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INSTRUCTIONAL DESIGN FOR DEAF STUDENTS: AN EXPERIMENTAL STUDY
OF MULTIMEDIA INSTRUCTION AND COGNITIVE LOAD

DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Education in the
College of Education
at the University of Kentucky

By

Soraya Cooper Matthews

Lexington, Kentucky

Director: Dr. Gary J. Anglin, Professor of Education

Lexington, Kentucky

2016

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ABSTRACT OF DISSERTATION

INSTRUCTIONAL DESIGN FOR DEAF STUDENTS: AN EXPERIMENTAL STUDY OF MULTIMEDIA INSTRUCTION AND COGNITIVE LOAD

Given that students who are deaf face learning challenges as a result of delays in language acquisition and reading comprehension skills, educators presume that the use of multimedia will aid in comprehension of novel information as it does with hearing students. This study examined the impact of multimedia on comprehension and cognitive load for students who are deaf. More specifically, this study aimed to determine whether there is a significant difference in the learning comprehension and cognitive load of deaf students exposed to two multimedia formats, compared to students exposed to a single format. Research participants were 64 students recruited from the student population at an institution of higher learning for students who are deaf in eastern United States. Participants were randomly assigned to one of three instructional treatments: text-only, picture-plus-text, or picture-plus-sign language. Instructional treatments were developed into online instructional modules and delivered through a web-based learning management system. Statistical analysis of comprehension test scores found significant difference between picture-plus-text treatment and text-only treatment on learning comprehension; no statistical significance between text only and picture-plus-sign language and no statistical significance between picture-plus-text and picture-plus-sign language on learning comprehension. Statistical analysis of NASA-TLX scores found a significant difference between the text-only treatment and the picture-plus-text and between text-only treatment and picture-plus-sign language treatment on cognitive load; and no significant difference between picture-plus-text and picture-plus-sign language treatment on cognitive load.

KEYWORDS: Deaf, Multimedia, Visual Learning, Cognitive Load Theory,
Instructional Design, NASA-TLX

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October 30, 2016
Date

INSTRUCTIONAL DESIGN FOR DEAF STUDENTS: AN EXPERIMENTAL STUDY
OF MULTIMEDIA INSTRUCTION AND COGNITIVE LOAD

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DEDICATION

To you Mother, for all of what you always said I could be.

I am because You were.

Rest in Heaven

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CHAPTER ONE: INTRODUCTION

Scope of the Study

Investigators studying multimedia and visual learning among deaf students have demonstrated favorable effects in content comprehension accompanied with formats that encompass a variety of visual modalities, visual media, and adjunct visual aids (Kelly, 1998; Dowaliby & Lang, 1999; Horney & Anderson-Inman, 1999; Loeterman, Paul, & Donahue, 2002; Lang & Steely, 2003; Gentry, Chinn, & Moulton, 2005; Yoon & Kim, 2011). Yet there is still more to explore. There exists a large body of empirical studies among normal hearing students that have concluded that the dynamic design of multimedia, which may consist of multiple types of media, combined modalities, and audio and visual cues, can have an advantageous effect on learning outcomes, depending on effective design measures (Mayer, 2005, 2009b; Mayer & Anderson, 1991; Mayer, Heiser, & Lonn, 2001; Mayer & Moreno, 2002, 2003; Tabbers, Martens, & Van Merriënboer, 2004). These studies are rooted in theories that adhere to certain constraints and characteristics of the learner's working memory. With consideration of the cognitive architecture of working memory, studies among deaf students suggest that working memory and cognitive processes are similar to hearing students in the processing of novel information (Wilson & Emmorey, 1997a, 1997b, 1998, 2000, 2001; Emmorey, 2002). These studies also suggest further consideration be given for the processing of sign language in working memory. The ambiguity of a language modality that is both verbal (linguistic) and visual might pose an additional challenge on working memory (Emmorey, 2002). Because of the unique language properties of sign language, multimedia that incorporates sign language may have the potential to enhance learning

and reduce cognitive load for deaf students (Emmorey and Wilson, 2004). The purpose of this study is to determine whether deaf students who are exposed to certain multimedia conditions perform better on a transfer test than with a single media condition; and to measure and compare the cognitive load experienced by deaf learners within the various multimedia formats. It is hypothesized that learning will be more efficient in the multimedia condition containing sign language than with the single condition of text-only, and that the sign language format presents a similar cognitive load benefit in deaf students as auditory language present in a dual mode condition with hearing students.

Background

Deaf and hard-of-hearing students face the considerable challenge of learning in an educational environment that is designed for and caters to students without any disabling characteristics. Being deaf means that a student cannot hear, but it often means that students do not experience the benefit of incidental learning (Allen, 1986), have delayed and/or lack language skills (especially in English and reading), and require specially designed instruction that accommodates the deaf in order to learn successfully. While deaf students face these challenges and disadvantages, due to the high stakes accountability system, they are still expected to learn and excel at the appropriate grade level alongside their hearing peers who do not face such obstacles. Thus, one of the most challenging tasks facing educators of deaf students today is designing instruction with grade-level content that addresses challenges associated with learning in a not-so-deaf-friendly environment.

While there are many exceptions, children who are born and grow up deaf typically do not possess the experiences (prior knowledge), cognitive skills, and linguistic

base necessary to achieve reading fluency beyond a fourth grade level (King & Quigley, 1985; Allen, 1986), and therefore struggle with content that is presented on par with grade-level expectations—especially in high school and college. Reading fluency and comprehension are likely the most important factors that influence the access to academic information and participation in any learning environment (Gentry et al., 2005). Despite many years of research in this area, reading comprehension in deaf students still remains consistently lower than same-age hearing peers (Allen, 1986, 1994; Marschark, 1993). Although deaf students have the same learning potential as their hearing counterparts, the considerable delay in the development of English language vocabulary interferes with learning to read (Quigley & Paul, 1989; Bradley-Johnson & Evans, 1991). In a survey conducted at Gallaudet University in 2013, researchers found that literacy, among other areas, was cited as a major barrier that prevents deaf and hard-of-hearing students from achieving their academic, linguistic, and social-emotional potential (Szymanski, Lutz, Shahan, & Gala, 2013).

Low literacy levels are a major concern in the deaf community and affect deaf students' ability to learn in the classroom and succeed within society. Educators of the deaf are faced with the instructional challenges of accommodating for reading comprehension performance of their students, while at the same time providing well designed instruction that will facilitate maximum learning of grade-level content (Nikolarazi, Vekiri & Easterbrooks, 2013). Teachers are tasked with designing and differentiating instruction for deaf and hard-of-hearing students in order to respond to their comprehension needs, enhance their access to grade-level curriculum, and maximize their learning (Nikolarazi et al., 2013).

A key element of differentiated instruction and learning with regard to deaf and hard-of-hearing students is the design of visual learning material (Nikolarazi et al., 2013). Students who are deaf are instinctively visual learners and therefore benefit from an intentional use of visual techniques, visual strategies, and visual education materials to help compensate for reading weaknesses (Dowaliby & Lang, 1999). Educators presume to assist deaf students by adapting instructional materials to aid in the cognitive processing of novel information and compensate for reading inadequacies by using multimedia technology (King & Quigley, 1985). So, is multimedia the answer?

Learning With Multimedia

A large body of empirical research has concluded that the dynamic design of multimedia, which may consist of multiple types of media, combined modalities, and audio and visual cues, can have either an advantageous or an adverse effect on learning outcomes for novice learners, depending on their ability to effectively utilize and adhere to certain constraints of working memory (Mayer & Anderson, 1991; Mayer, Heiser, & Lonn, 2001; Mayer & Moreno, 2002, 2003; Tabbers et al., 2004; Mayer, 2009a). Multimedia studies compare design combinations of media such as a spoken language, and visuo-spatial information such as pictures, animations and charts, and/or printed text. Such studies assert that the combination of media, when designed properly, is more effective than any one presented alone (Mayer & Moreno, 2003). The population for these studies lends itself to the typical college-educated student of normal hearing and average cognitive abilities. While the deaf student population is presented with much of the same instructional challenges as their hearing peers, only a handful of studies have formally researched the design effects of multimedia within the deaf and hard-of-hearing

learning environment (Reynolds & Rosen, 1973; Diebold & Waldron, 1988; Kelly, 1998; Dowaliby & Lang, 1999; Gentry et al., 2005; Nikolarazi et al., 2013).

Learning materials for students who are deaf incorporates many types of standard multimedia such as text, pictures, and instructional videos with and without captions, animations, simulations, avatars, and graphic organizers. Research that examined the effectiveness of various instructional materials for deaf children showed that pictorial formats, along with simple or brief text, helped students to learn and recall more information and proved beneficial in content comprehension (Reynolds & Rosen, 1973; Reynolds & Booher, 1980; Robbins, 1983; Wilson & Hyde, 1997; Walker, Munro, & Richards, 1998). Other research focusing on the application of multiple media has also provided favorable results in the comprehension of content when accompanied with a variety of visual modalities, visual media, and adjunct visual aids (Kelly, 1998; Dowaliby & Lang, 1999; Horney & Anderson-Inman, 1999; Loeterman et al., 2002; Lang & Steely, 2003; Gentry et al., 2005; Yoon & Kim, 2011). According to Gentry et al. (2005), multimedia material may not only improve comprehension of a particular text, but also contribute to deaf students' overall development of literacy skills and motivation because they provide access to rich linguistic experiences. Multimedia materials for deaf students incorporate many types of the typical media used with hearing students with one exception—one that is unique to deaf population: sign language. Sign language is a visual language that consists of hand signs, gestures, body movements, and facial expressions to communicate a thought or idea. Sign language is a primary communication modality used with deaf students.

When deaf students learn using sign language, they become cognitively engaged in the learning process. According to Emmorey (2002), the working memory treats sign language as both a phonological and a visual modality, stimulating the different components of the cognitive architecture. Students who are deaf process sign language in much the same way as a hearing person processes spoken language within working memory. In a series of studies, Wilson and Emmorey (1997a, 1997b, 1998, 2000, 2001) took up the challenge of investigating how a sign language modality might shape the architecture of working memory for students who are deaf. These studies provide insight for understanding the uniqueness and constraints of working memory for deaf students and the mental processing of sign language. However, there needs to be more research in the area of design of instructional material that adheres to the constraints of working memory in order to avoid overloading working memory. Educators of students who are deaf have a duty to adhere to principles of proper design of instructional multimedia that best utilize cognitive processes within working memory.

One effective theory used to guide principles of designing instruction and adheres to the cognitive processing and architecture of working memory is Cognitive Load Theory (CLT) (Sweller, 1994). Sweller, Ayres, & Kalyuga, (2011) noted that CLT was explicitly developed as a theory to facilitate instructional design based on knowledge of the human cognitive architecture. Cognitive Load Theory, when applied appropriately, can ensure the full utilization of working memory and aid in designing materials that compensate for cognitive processes, thereby reducing memory load and improving learning outcomes (Sweller et al., 2011). Therefore, given the premise of which the

concept of CLT originated, it conceivably is fully applicable to deaf learners, who might display varying characteristics of cognitive processing abilities.

Cognitive load theory (CLT) embodies the aspects of human cognitive architecture that are relevant to instruction along with the instructional consequences that flow from that architecture (Sweller et al., 2011). Mayer & Moreno, (2003) proclaimed that CLT was formulated to provide instructional guidance that accounts for the limited duration and capacity of working memory when faced with novel information entering via short-term memory. The theory provides guiding principles for dealing with students who have differing knowledge levels, differing cognitive abilities, and differing working memory characteristics (Sweller, 2004). Taking into consideration the unique characteristics of working memory when processing sign language, CLT provides a basis of which to develop effective instructional material (Emmorey, 2002) for students who are deaf. CLT intends to assist in the design and presentation of information in a manner that encourages learner activities that optimize intellectual performance (Sweller, Van Merriënboer, & Paas, 1998).

Statement of the Problem

Deaf students are expected to learn grade-level curriculum at the same pace as their same-age hearing peers, yet they face learning challenges as a result of delays in language acquisition and reading comprehension skills. Educators of the deaf face a significant challenge to design instruction that is both on grade level and accommodates for weaknesses in reading comprehension. Therefore, educators presume that the use of multimedia will aid in comprehension of novel information (King & Quigley, 1985) when presented to students who are deaf. The goal of educators is to design multimedia

instruction that, both, aids in the comprehension of learning materials and that does not cause extraneous load on the learner (Kester, Kirschner, & Van Merriënboer, 2005).

Purpose of the Study

The purpose of this study is to examine and analyze the impact of multimedia instruction compared to text-only instruction on learning comprehension among students who are deaf. This study seeks to address two questions:

- 1) Is there a difference in learning comprehension of deaf students who are exposed to multimedia formats of picture-plus-text and pictures-plus-sign language when compared to a single mode format of text-only?
- 2) Does either the picture-plus-text or pictures-plus-sign language format produce significantly less cognitive load when compared to the text-only format for students who are deaf?

CHAPTER TWO: LITERATURE REVIEW

The purpose of this study is to examine the impact of multimedia on learning comprehension for deaf learners. This chapter reviews literature and primary research studies that are vital to the exploration of this research. First, the chapter begins with a thorough review of studies focused on various multimedia approaches designed for deaf students. Second, the chapter provides the theoretical framework of CLT and its basis for the design of multimedia; and further explores cognitive architecture of working memory as the basis of multimedia learning. Third, this chapter provides a review on sign language as a separate modality and its impact alone on working memory load. The goal of this chapter is to compile a comprehensive rationale for exploring the questions addressed in this research. The literature was retrieved from searches of numerous online databases including ProQuest, ERIC, and Dissertation databases for pertinent keywords and an examination of references cited by Sweller et al. (2011).

Effect of Multimedia Design for Deaf Students

The few studies that have investigated pictorial and printed text formats with deaf students support the notion that the comprehension of content can be maximized by presenting the student with simplified text and a pictorial presentation (Reynolds & Rosen, 1973; Reynolds & Booher, 1980; Robbins, 1983; Diebold & Waldron, 1988; Wilson & Hyde, 1997; Walker et al., 1998).

In a study conducted by Reynolds and Rosen (1973), three printed instructional formats were created to portray the parts of the central nervous system: 1) textbook condition consisting of narratives using fewer complex vocabulary and grammatical structures; 2) an individualized condition that contained text, drawings, learning

objectives, self-pacing and immediate question and feedback; and 3) the pictorial conditions that consisted of 26 picture displays each accompanied by labels and descriptive phrases. In a pre-test/post-test design, 52 hearing-impaired students were tested on their comprehension and retention one day after the treatments were presented. In a second experiment, $n=94$, students were given the same treatments with a 13 day delay in post-test. Results in Experiment 1, where the post-test was given the following day, showed significantly higher scores for the pictorial format group than the textbook format group, while the individualized format group scores were at the intermediate level. A similar trend was demonstrated in Experiment 2.

For both experiments, post-test gain scores for the pictorial conditions were higher than the gain scores for the textbook and individualized conditions. In Experiment 1, the difference between scores for the pictorial and textbook groups is significant ($p<.05$). In Experiment 2, the difference in gain scores between the pictorial and textbook group is also significant ($p<.02$). Upon further analysis, differences between Experiment 1 and Experiment 2 are all highly significant ($p<.001$) for the textbook, individualized, and the pictorial formats; and reflect a decline of retention over the longer 13 day post-test interval in Experiment 2.

Reynolds and Rosen (1973) provide support for the effectiveness of pictorial presentation of information to hearing-impaired student. The use of pictorial instruction facilitate both comprehension and retention of novel information, above those of the textbook and individualized formats. Reynolds and Rosen (1973) claim that the heavy emphasis on the verbal print channel for presenting information found in the individual and textbooks format nullified any benefits for the hearing-impaired students who have

deficient language and reading skills. The pictorial presentation was the most effective instructional format for the students in this experiment. Given the time period of this study, this may have been the closest form of multimedia for students who were deaf.

Language deficiency and poor reading skills are common trends among deaf studies where pictures and other visual supports are used to supplement or replace text. Similar to Reynolds and Rosen (1973), the study (n=56) conducted by Reynolds and Booher (1980) compared the effectiveness of pictorial and verbal information in printed instructional material with deaf students in four separate treatments: 1) all-pictorial; 2) all-verbal; 3) high pictorial-low verbal; and 4) high verbal-low pictorial.

The all-pictorial format consisted of information that was presented through a single channel of displays with no printed verbal information, and only alphanumeric symbols that identified the sequence of actions to be performed. The all-verbal format consisted entirely of printed verbal and numerical information arranged in simple sentences that identified the controls, displays, and tables to be used and described the action-steps to be followed. No pictures were included in this format. The high pictorial-low verbal condition depicted the same diagram as the all-pictorial format in addition to some related printed words and phrases identifying specific controls, displays and tables and brief descriptions of the action-steps to be followed. In the high verbal-low pictorial format, information was presented primarily the same way as the verbal information used in the all-verbal format, but some related pictorial displays consisted of an outline drawing of the entire apparatus with word labels and arrows that indicated specific controls and displays.

Students were randomly assigned to one of four treatments, with operational instructions for a programmable task simulator device. Performance was analyzed and measured according to error rate and time on-task completion of operating the apparatus. Reynolds and Booher (1980) found that the all-pictorial treatment provided the shortest mean task completion time, but with a high error rate. The high pictorial-low verbal format produced the lowest mean error rate and the second shortest task completion time (not significantly different from the all-pictorial format) and emerged as the most effective instructional design.

Using a pre-test/post-test measure of comprehension, Diebold and Waldron's (1988) study (n=60) presented four different instructional formats of science concepts to hearing-impaired students. Students were randomly assigned to either the standard text, simplified text, simplified text/labeled diagram, or the labeled diagram formats. The researchers further predicted that the subjects would show better comprehension when presented with simplified text that contained fewer complex language patterns than standard text. It was further predicted that the presentation of pictorial information would also enhance comprehension. The simplified text format yielded the highest mean gain score between pre-test and post-test. Simplified text/labeled diagram and labeled diagram formats produced mean gain scores significantly better than the standard text format. The simplified text, simplified text/labeled diagram and labeled diagram formats utilized controlled language principles and all three produced mean gain scores significantly better than the standard text format at the .05 level. The labeled diagram was the only format to yield significant comprehension gains for both groups. Diebold and Waldron's (1988) study demonstrated that systematically designed printed instructional material can

enhance learning and comprehension for hearing-impaired student. Diebold and Waldron (1988) suggest further research in visual/pictorial design as a medium of instruction for deaf learners.

Furthermore, Walker et al. (1998) presented an investigation (n=60) that recorded the use of an intervention to teach inferential reading to underachieving readers using pictorial material and printed text. The investigation was comprised of two experimental and two control groups. The experimental groups were given one lesson per week (for 30 weeks) of instruction that was designed using pictorial material in conjunction with written text. Experimental Group 1 was instructed by the researcher; while Experimental Group 2 was instructed by the students' regular teachers. Group 3 and Group 4 were comprised of control groups. Control Group 3 received one lesson per week for 30 weeks by their regular teachers using a conventional reading comprehension program. Control Group 4 did not receive any specific reading comprehension intervention other than the one that was included in the regular curriculum. A pre-test and post-test model measured literal and inferential reading tasks for each group after the 30 lessons using planned comparisons and analysis of covariance.

Walker et al. (1998) found that the researcher-led experimental group (Group 1) showed an improvement in inferential comprehension ($t=5.1$), but not in literal comprehension. This improvement was equivalent to an average 2.4 grade levels. The teacher-led experimental group (Group 2) improved in literal ($t=6.6$) and inferential comprehension ($t=4.2$), which equated to a 1.7 grade-level improvement. The control groups showed smaller gains in improvement with conventional-program group (Group 3) showing improvement only in literal reading ($t=2.7$) and no-intervention group (Group

4) showing no improvement, which equated to 1.2 and 0.4 grade-level improvement respectively. Walker et al. (1998) concluded that the purposeful intervention to facilitate reading comprehension development in children who are deaf or hard of hearing has the potential to prevent deaf students from falling further behind their peers with normal hearing. The pictorial intervention program used in this study was effective in improving reading comprehension levels of readers who are pre-lingually deaf.

In a single-subject design study, Kelly (1998) utilized 10 silent movie videos depicting humorous, raucous action from the early twentieth century to foster comprehension of relative clause and passive voice sentences during reading with 12 subjects. The meanings of the stories were conveyed almost exclusively through the actions of the characters within the context of the stories causing comprehension to be independent of language competence. The movies base their instructional effectiveness partly on the premise of being an amusing experience in contrast to traditional comprehension programs. Multiple baselines provided the design in order to test the effectiveness of the video instructional program. Four different areas of performance were measured: 1) comprehension of passive voice sentences; 2) comprehension of passive voice control sentences; 3) comprehension of relative clause sentences; and 4) comprehension of relative clause control sentences. Kelly (1998) found that 8 of the 12 applicants resulted in significant improvement in comprehending either relative clause or passive voice sentences. Two subjects who participated in the long-term follow-up testing maintained 100% accuracy six months after completion of the video program. Kelly (1998) determined that silent movies constitute a source of logical input that can foster comprehension of relative clause and passive voice sentences.

In a study (n=144) by Dowaliby and Lang (1999), five instructional conditions were compared: 1) text-only; 2) text and content movies; 3) text and sign movies; 4) text and adjunct questions; and 5) all of these combined (full condition). These conditions were compared to determine the effectiveness on direct learning as measured on a post-test for retention. The researchers presented computer-based instruction that consisted of 11 lessons on the human eye, its function, and care. The text-only conditions consisted of one to three sentences, comprised of 12 to 31 words, per lesson. The grade-level equivalent of presented text was calculated between the ranges of 5.5 to 12. The adjunct questions condition was coupled with multiple-choice answers that provide feedback for responses that were verbatim reproductions of part of the lesson texts. The sign movies were representation of the lesson text, and were presented in American Sign Language. The content movies were animated pictorials that exemplified the lesson content.

In the post-test analysis, the adjunct questions and full condition yielded a significantly greater post-test performance than the text-only, content movie, and sign movie conditions (all $ps < .05$), for low and middle reading levels. No significant difference was found among any of the conditions for high reading level subjects. Dowaliby and Lang (1999) noted that despite the visually informative characteristic nature of the content movies, they did not induce learner engagement, indicating that students perhaps had not fully attended to the provided visual aids. In regards to the sign movie condition, Dowaliby and Lang (1999) contended that sign representations may only produce learning performance benefits when the difficulty level of the text sufficiently surpasses the ability of the reader. However, when both of these conditions were included with the full condition presentation, results yielded more than twice the

proportion of participants with a ceiling effect on the post-test, as did the adjunct question condition, with a difference approaching significance of ($p < .07$). Dowaliby and Lang (1999) further presumed that these factors taken together, suggest that either or both of the sign and content movies may have worked synergistically with the text and adjunct questions to the benefit factual learning by the participants in the current study.

Gentry et al. (2005) conducted a study ($n=25$) using a repeated measure design for single subjects where stories were presented in four multimedia formats: 1) print-only; 2) print plus pictures; 3) print plus digital video of sign language; and 4) print plus pictures plus digital video of sign language to 25 native ASL users. Participants of the study met three specific criteria: 1) third or fourth grade reading level; 2) average IQ; and 3) use of language as the primary means of communication. The goal of this study was to assess the effectiveness of the different presentation options in improving reading skills of deaf students. The transfer of factual information was measured by a story-retelling activity where participants were asked to recall aspects of the story presented to them randomly through the print-only, print plus pictures, print plus digital video of sign language, and print plus pictures plus digital video of sign language multimedia formats. The results of the study, according to a repeated measure ANOVA, indicated that comprehension was weakest when the stories were presented in a print-only format and strongest when stories were presented in the print plus pictures format (Gentry et al., 2005). Gentry et al. (2005) noted a surprising result according to the Tukey post-hoc analysis that indicated no statically significant difference between the print plus pictures when compared to the print plus pictures plus sign language formats.

Nikolaraizi et al.'s (2013) study (n=8) examined students reading comprehension in the utilization of a multimedia software called See and See. The See and See program is comprised of two interfaces—one for the student and one for the teacher. See and See was developed to focus on deaf students' need for visual resources and included electronic texts, videos, pictures, and sign language, as well as concept maps. The pictures closely correspond to the text content and present relations among information. The concept maps illustrate the main elements of the narrative text and are presented according the story's structure. In order to avoid the overload of working memory of multiple redundant resources, the software does not permit students to access more than one visual aid simultaneously. Students control their own pace of their reading and they control when and how many times they want to view each of the visual aids.

Summary

Pictorial and multimedia formats can be an effective instructional design in facilitating the learning process and enhancing student comprehension. However, more empirical research is needed in the areas of pictures plus text versus text only, multiple visual formats, animation, and the use of sign language integrated with pictures versus text formats with deaf students. While previous studies alone do not provide a valid justification for the use of multimedia, they do provide a basis of which to continue to explore its utility. In order to fully understand how the results of previous studies provide a context of which to explore a more formal instructional theory based on design strategies, a review of the cognitive structure of working memory within the typical human architecture including a brief perspective of processing sign language for deaf learners is now provided.

Cognitive Architecture: Working Memory Models

One of the earliest models of working memory and its processes was introduced by Allan Paivio (1969), who proclaimed that verbal and non-verbal data are processed in different subsystems of working memory and both subsystems have separate, but limited processing capabilities that cannot easily be exchanged between the systems. This theory is called the *dual-coding theory* because it proposes two independent memory codes. The dual coding theory provides an important foundation for subsequent cognitive architectures because of this distinction (Sweller et al., 2011). Paivio (1969) claimed that pictures typically result in better memory than prose, which usually results in better memory than abstract words. Further, Paivio (1969) claimed that images are more effective than words because they utilize a second kind of memory code that is independent of the verbal code. It should be noted that dual coding does not propose an integration of the verbal and visual codes because the two codes are only better than a single if they are, at least, partially independent (Paivio, 1969). Rather the integration occurs at the design level of the material that will be learned.

Another prominent model that bares a close resemblance of the early work of Paivio, and also distinguishes between the functions of verbal code and visual code is the Baddeley and Hitch (1974) memory model. This model consists of three components: 1) a phonological loop responsible for maintaining and manipulating verbal information; 2) a visuo-spatial sketchpad responsible for maintaining and manipulating visual or spatial information; and 3) a central executive responsible for selecting strategies and integrating information. One notable difference of Baddeley and Hitch's (1974) model is that the verbal code emphasizes phonological information as oppose to the semantic information

claimed in Paivio's dual coding theory. This early model by Baddeley and Hitch (1974) displays inherited limitations for being somewhat irrelevant for multimedia learning in that it does not provide any supportive means for the integration of both visual and verbal information. Both, the Paivio (1969) and the early Baddeley and Hitch (1974) models are more useful for studying the independent input and storage of verbal and visual codes rather than for studying the integration of the two modes together.

In 2001, Baddeley proposed a revised model that contained a fourth component, the episodic buffer. This new component acts as a limited capacity storage (short-term memory) that integrates information from the visuospatial sketchpad and from the phonological loop (working memory) and channels information to and from the central executive (long-term memory) (Baddeley, 2001). Therefore, the episodic buffer is the storage system that can integrate memory codes from different modalities (Baddeley, 2001). This newly revised working memory model emphasizes both the integration of multimodal codes and the interaction between short-term and long-term memory, making it more relevant to multimedia learning.

This memory model is also more relevant to the study of sign language and how it is processed in working memory. Studies that focus on the cognitive functions of the deaf and the function of sign language within working memory, have also adopted the theory of Baddeley's (2001) memory model (Wilson & Emmorey, 1997a, 1997b, 1998, 2000, 2001; Emmorey & Wilson, 2004; Boutla, 2003, Brownfield, 2010). The architecture of the Baddeley model has provided a useful framework for investigating working memory's processing of sign language among deaf learners (Emmorey, 2002). Studies that seek to investigate if American Sign Language (ASL) is processed in working

memory using the phonological loop or the visuospatial sketchpad have presented with more questions than answers (Brownfield, 2010).

In a dissertation study, Brownfield (2010) sought to determine if a difference exists between the two visual languages modalities of ASL and print by comparing the forward and backward recall of digits and letters. Thirty-eight deaf signers were recruited from Gallaudet University to be used for data analysis within this study. This study consisted of a three-way, within-subject design with three independent variables and one dependent variable. The three independent variables were: 1) direction of recall (i.e., forward vs. backward); 2) format (i.e., digits vs. letters); and 3) presentation (i.e., ASL vs. print). Results showed that only the direction of recall independent variable displayed a significant main effect. The digit and letter formats were lower for ASL and print when compared to other studies using hearing speakers. Brownfield's (2010) findings suggested that the phonological loop is best for tasks of sequential processing and recalling items in reverse order is a novel task that requires additional cognitive resources. Brownfield (2010) suggests that since ASL involves both sequential and simultaneous processing, that perhaps both the phonological loop and the visuospatial sketchpad are used in retention of linguistic sequences. Brownfield (2010) posits that hearing bilinguals, and especially pre-lingually deaf signers, utilize the visuospatial sketchpad to some extent as visual input that is encoded into memory. Thus, an alternate possibility for the lower spans for ASL when compared to spoken English can be attributed to the transitioning of visual input from the visuospatial sketchpad to the speech-based/sign-based loop or operating both at the same time. As a result, visual

spans—regardless of whether they are print or ASL—are shorter when compared to auditory spans (Brownfield, 2010).

The magnitude of studies focused around multimedia learning, in some way, attributes its design features to one of the two previously explained working memory models introduced by Pavio or Baddeley.

Cognitive Load Theory (CLT)

In a text co-authored by Sweller, Ayres, and Kalyuga (2011), Cognitive Load Theory (CLT) is noted as a unified and holistic theory that emphasizes the human cognitive architecture, domain-specific knowledge, and instructional effects based on numerous randomized controlled experiments. CLT adopted the premise of memory models and ingrained the ideas of short-term memory, working memory, and long-term memory as the basis for guidelines for designing instructional media that adheres to how learning takes place (Sweller et al., 2011). CLT posits that the major purpose of instruction should be to increase secondary knowledge held in long-term memory. The role of long-term memory in learning and problem solving is to provide a purpose and function for instruction. The purpose of instruction is to increase knowledge in long-term memory. If nothing has changed in long-term memory, nothing has been learned. (Sweller, Ayres, & Kalyuga, 2011). Therefore, information needs to be presented in a manner that attempts to reduce unnecessary processing load. In order to ensure novel information reaches long-term memory, CLT devised instructional procedures that reduce extraneous load and so decrease the working memory resources. This allows more resources to be devoted to cognitive load germane to learning.

Types of Load

According to past CLT research, working memory can be affected by three types of cognitive overloads depending on its function (Sweller, Van Merriënboer, & Paas, 1998; Paas, Renkl, & Sweller, 2003; Van Merriënboer & Sweller 2005). The first, intrinsic load, is one that is imposed by the intrinsic nature of the instructional material and cannot be directly influenced by the instructional design. It is simply caused by the interaction between the material being learned and the expertise of the learner (Sweller, Ayres, & Kalyuga, 2011). This directly deals with the memory's limited ability to hold approximately seven elements simultaneously and the extent of interactivity of those elements (Sweller, Van Merriënboer, & Paas, 1998). If the elements are non-interacting and can be learned in isolation, intrinsic cognitive load is low. Paas, Renkl, & Sweller, (2003) provided an example of low element interactivity as learning the 12 function keys effect in a photo editing program. Each task can be learned in isolation. In contrast, when one task builds on the knowledge of another task, intrinsic load can become high (Van Merriënboer, Schuurman, De Croock, & Paas, 2002). For example, learning to edit a photo on a computer is a task with high element interactivity. The elements of high-element interactivity material can be learned individually, but cannot be understood until all elements are processed simultaneously (Paas, Renkl, & Sweller, 2003). A remedy for intrinsic load is to reduce whole-tasks into categories of simple-to-complex tasks classes, where one task builds on the prior. In this event, each new task classes are in the learner's proximal zone of development (Van Merriënboer, Schuurman, De Croock, & Paas, 2002).

Given what is known about intrinsic load, it is vital that the human cognitive architecture be able to handle high-element interactivity material (Paas, Renkl, & Sweller, 2003). This is done by combining the efforts of working memory and long-term memory in the construction of schema development. Paas et al. (2003) describe schemas as cognitive constructs that incorporate multiple elements of information into a single element. If employees who drive to work each day were forced to make a detour on one street, most would be able to make the adjustment without additional guidance. A schema already exists in long term memory for the route that is comprised of multiple streets, turns, and traffic patterns, and therefore can be manipulated in working memory when a change occurs. This is the process that allows the human cognitive architecture to handle complex material that may otherwise exceed the capacity of working memory (Paas et al. 2003). Cognitive Load Theory focuses on the interaction between information structures and cognitive architecture; particularly concerned with the manner in which information presented may impose unnecessary cognitive load for the learner (Paas, Renkl, & Sweller, 2003). Unnecessary load interferes with schema construction and is referred to as extraneous load. Extraneous load, refers to cognitive overload that arises when learners interact with the instructional material influenced by instructional designers (Kester, Kirshchner, & Van Merriënboer, 2005). Extraneous load is due largely in part to designs created without reference to the limitations of working memory. It is caused entirely by the format of the instruction rather than by the intrinsic characteristics of the material. For example, an instructional process that requires a learner to determine the order a series of short videos explaining the steps to operate a program should be viewed, would likely impose a heavy extraneous load because working memory

resources must be used for activities that are irrelevant to the schema construction of using the program.

Both intrinsic and extraneous cognitive load are additive and may interfere with learning. Together they determine the total cognitive load imposed upon working memory by material that needs to be learned (Sweller, Ayres, & Kalyuga, 2011). Thus, if the total working memory resources needed to deal with the load imposed by intrinsic and extraneous cognitive load exceed the available resources in working memory, the cognitive system fails and learning does not occur (Sweller, Ayres, & Kalyuga, 2011).

A third load, germane load, is also influenced by the design of instructional material, whereas extraneous cognitive load interferes with learning, germane cognitive load enhances learning (Paas et al., 2003). With germane cognitive load, resources are devoted to schema acquisition and automation (Pass et al., 2003). Learners are encouraged to engage in conscious cognitive processing that is directly related to the construction of schemas. Since all three loads are additive, this will only work if the sum of intrinsic cognitive load, plus extraneous cognitive load, plus germane cognitive load, stays within working memory limits (Sweller, Van Merrienboer, & Paas, 1998). The aim of an instructional designer is to reduce extraneous cognitive load so that the greater amount of working memory resources are devoted to intrinsic cognitive load that is germane to the learning process (Sweller, Ayres, & Kalyuga, 2011).

When the total cognitive load is too high, processing novel information may become difficult and learning may cease. It can be increased or decreased by changing the way content is learned. If the intrinsic load is high, the level of extraneous load,

which deals with how instruction is designed, becomes critical (Sweller, Ayres, & Kalyuga, 2011).

Cognitive Load Theory and Instructional Design Effects

Understanding the significance of learning effects in instructional design helps guide the process of adhering to working memory limitations and avoiding extraneous load. There are a number of learning effects that are considered and have been noted in previous CLT studies. One of the most familiar effects, especially in math, is the worked-out example, design effect. With a worked example, learners are given a state along with a desired goal and an example solution. However, these examples do not force learners to study them carefully. The completion effect is very similar to the worked example. It presents a given state, goal, and a partial solution (Van Merriënboer, Kirschner, & Kester, 2003). Reverse effect tasks provide the learner with both a goal and the solution, then ask which given situations the solution may be helpful to reach. These design effects serve as a guide for instruction that is presented in a single mode. Other design effects such as split-attention, spatial contiguity, and modality affects that focus primarily on the optimal design and use of multiple sources and modes of communication, and are more applicable to the use sign language in instructional design found in this study.

Multimedia Learning Effects

Multimedia instruction incorporates a variety of pictures, text, and sounds to facilitate learning and is typically delivered by computer. CLT assumes that the dynamic and combined use of this media causes problems for the learning process. The split-attention effect involves the process of placing text and a related picture side by side, thereby reducing unnecessary use of memory of looking in separate locations to make

required connections. (Sweller et al., 2011). This design helps facilitate the learning process. When learners are required to integrate multiple sources of information that are separate in space and time, extraneous load is created. Instructional design that adheres to the split-attention effects, replaces the multiple sources of information with a single integrated source (Sweller et al., 2011). Sweller, among others, have shown belief that the physical integration of multiple sources of information resulted in improved learning outcomes (Tarmizi & Sweller, 1988; Sweller, Chandler, Tierney, & Cooper, 1990; Chandler & Sweller, 1991, 1992; Kalyuga, Chandler, & Sweller, 1998; Mayer, 1998). The next design effect discussed specifically addresses the physical space between the graphics and text.

With the spatial contiguity effect, students learn more deeply from multimedia explanations when words and corresponding pictures are presented near to, rather than far from each other (Mayer & Moreno, 2003). The spatial alignment of words and pictures appears to be a proven technique for reducing cognitive load (Mayer & Moreno, 2003). Mayer, among others, have shown through a number of experiments that multimedia instruction was more effective when graphical and text information were presented close to each other rather than spatially separated (Moreno & Mayer, 1999; Mayer 2003). In a study demonstrating spatial contiguity effect, which involved a lightning explanation, students in an integrated presentation group generated 43% more creative solutions on a problem-solving transfer test than did those of the separated presentation group (Moreno & Mayer, 1999). It is notable that the two previously described effects takes into consideration the use of both graphical and text forms of information, both of which are visual stimulations.

A third design effect, modality effect, is based on the simultaneous presentation of information through different modes of communication such as visual and auditory modes. Research by Penney (1989) suggests that in presentation materials consisting of a mixture of auditory and visual modalities cues, working memory is more effective due to the utilization of its capacity. The amount of information that working memory can process may be in part determined by the modality of the presentation. Therefore, modality effect assumes that working memory can be increased by presenting information in a dual-modality rather than a single modality (Sweller et al., 2011). One of the most cited examples of modality effect in the literature is the higher recall for lists of items when they are presented in both visual and auditory modalities rather than just one modality, as proven in a meta-analysis by Ginns (2005). According to the modality principle, words should be presented as an auditory narration rather than as visual on-screen text (Moreno & Mayer 1999). In the case of a visual-only multimedia presentation, Tabbers et al. (2004) claim that written text and pictures are both processed in the visual part of the working memory, and the processing capacity of this memory system must be split between the two sources of information, while the phonological part of the working memory remains unemployed, and its capacity is not used for information processing. However, if the same learning material is presented audio-visually, such as a picture and a narration, the spoken text can be processed in the phonological subsystem while the picture can be processed in the visual subsystem of the working memory. The theory is that because the available capacity in both subsystems can be utilized, more cognitive capacity is available for processing materials compared to the visual-only or audio-only content (Brunken, Plass, & Leutner, 2004). Based on a large body of

pragmatic research within the framework of CLT, the modality effect is known as one of the most consistently reliable and valid instructional design effects in multimedia learning because of its ability to utilize all functions of the working memory (Brunken et al., 2004). The argument here is that graphics and text presentation do not provide ultimate learning capabilities unless dually presented with an auditory stimulus, providing sufficient information to enable effective use of working memory.

Studies grounded within CLT's guidance on the design of multimedia are consistently effective on learning comprehension for subjects of normal hearing and comprehension abilities. Given what is known about the success of multimedia design with hearing subjects, this study aims to extend results found with hearing students to students who are deaf. In particular, the present study seeks to determine the effectiveness of multimedia design on comprehension when used with students who are deaf, and further, to determine if a multimedia format presents a lower cognitive load than a text only format.

Hypothesis

The hypotheses testing learning comprehension in this study was:

H1: There will be a significant difference in Comprehension Test scores with a higher mean test score for the picture-plus-text treatment when compared to the mean test score for the text-only treatment.

H2: There will be a significant difference in Comprehension Test scores with a higher mean test score for the picture-plus-sign language treatment when compared to the mean test score for the text-only treatment.

H3: There will be a significant difference in Comprehension Test scores with a higher mean test score for the picture-plus-sign language treatment when compared to the mean test score for the picture-plus-text treatment.

The hypotheses testing cognitive load in this study was:

H4: The text-only treatment will produce significantly higher cognitive load than the picture-plus-sign language treatment.

H5: The text-only treatment will produce significantly higher cognitive load than the picture-plus-text treatment.

H6: There will be a significantly higher cognitive load for the picture-plus-text treatment when compared to the picture-plus- sign language treatment

CHAPTER THREE: METHODOLOGY

This chapter discusses the methodology that was used during this quasi-experimental study, including an explanation of the population characteristics, instructional materials, instruments, treatments, and the study's procedure and design.

Population Characteristics

Research participants in this study were undergraduate students from an institution of higher learning for students who are deaf or hard of hearing. Participants were recruited via an email sent through the university's "list-serv" to all currently enrolled, undergraduate students. Participants were adult men and women, ranging in age of 18-24 years old. All participants were enrolled as full-time status in an undergraduate program at the university during the Spring 2016 semester. Each participant is deaf, knowledgeable of deaf culture, and fluent and capable of learning through sign language. Participants recruited for the study were required to meet a minimum self-report rating of "Advanced" skills in American Sign Language and possess a moderate-to-severe (or greater) hearing loss as indicated on a self-reporting pre-screen survey. The Pre-screen survey serves to allow participants to report their level of proficiency in sign language and to control for variances in hearing loss. In order to account for threats to internal validity of prior knowledge, there was a question on the self-reporting survey form about the student's current college major and minor. Given that the instructional content of the treatment is related to biology, those students whose major or minors include Biology or Health Sciences could pose a threat to prior knowledge, and therefore were excluded from the study. All other majors were acceptable for the study. Participants received a \$10 gift card of their choice, by email, upon completion of the study.

Treatments

Treatments were created and adapted from instructional resources from Dwyer and Lamberski's (1977) print materials, *How the Heart Works* (National Institutes of Health [NIH], 2011) web resources, and the English transcript of the sign language video, *To the Heart of the Matter* (Tourville, 2002). Instructional materials were developed into three computer-based instructional lessons. The three lessons were comprised of three different types of media: text, pictures, and sign language. Each of the three instructional lessons included either one or two of the types of media, creating three distinct treatments for the study. Figure 3.1 depicts the media format for each treatment. All three instructional treatments were uploaded as individual modules in an online learning management system. The software used to develop the online instructional modules included iSpring Suite and Quizmaker, Microsoft PowerPoint, and iSpring Learning Management System.

	Treatment	Text	Pictures	Sign Language
Instructional Modules Design Formats	T1			
	P+T			
	P+SL			

Figure 3.1. Diagram depicting the design formats of each treatment

Text-Only (T1)

In the text-only treatment, the text consists of 1,130 words that are written in a simplistic and concise format, and organized in five sections. The five sections of each

module are: 1) *What is the Heart*; 2) *Anatomy of the Heart*; 3) *Your Heart's Exterior – Right Side and Left Side*; 4) *Your Heart's Interior – Right Side and Left Side*; and 5) *Blood Flow*. Material was obtained from the National Institutes of Health (2011) website and the English transcript of the *To the Heart of the Matter* video, produced by Tourville (2002) in collaboration with the College of St. Catherine. This information is separated among nine primary slides, each averaging 100 words per slide. Information is presented in a bulleted format that enters and exits the screens to allow more focus and color enhancement of the on-screen text being learned. The text reflects a fifth grade reading level as indicated on the readability scale incorporated in the Microsoft Word software.

Pictures-Plus-Text (P+T)

In the pictures-plus-text treatment, slides incorporate the text exactly as included in the text-only condition. Each slide also contains a picture, or series of pictures, that depicts the same information explained in the text.

Pictures-Plus-Sign Language (P+SL)

In the picture-plus-sign language treatment, each slide contains a picture or series of pictures found in the picture-plus-text condition. Additionally, each slide is presented in sign language. The addition of sign language videos was incorporated from the *To the Heart of the Matter* (Tourville, 2002) video. The sign language videos portray the same information as presented in the text-only condition and is displayed at the exact same time as the corresponding picture or series of pictures.

Online Instructional Modules

Three separate instructional modules were designed and created based on three treatment formats. Modules were developed within and facilitated by the iSpring Learning Management System. Each module was comprised of the same instructional content divided among the different media used for each treatment. Each of the three instructional modules were designed to incorporate the treatments and other instruments pertinent to the study. Color, text size, arrows, and other enhancements were used to draw attention to the main ideas as participants interacted with instructional material. Participants were given a level of control as they progressed through each instructional module and they could choose to replay any slides or sign language video they viewed. Additionally, as participants progressed through the presentations, prior screens were available to be reviewed multiple times. To ensure interaction with the treatment materials, participants were required to view the entire sequence of instruction or sign language video clips at least once before they could proceed to the next screen; and any screen could be repeated as often as the participants deemed necessary. Prior to beginning the instructional lesson, all three of the modules included an introduction page that described the purpose of the study, procedures to be followed during the study, instructional content and its organization, and a description of what to do at the completion of the module.

Instrumentation

Three instruments were used for this study: a participant profile, a test of comprehension for assessing learning comprehension, and the NASA TLX for

assessment of perceived cognitive load experienced as a result of each of the treatment presentations (Dwyer & Lamberski, 1977; Hart & Staveland, 1988).

Participant Profile

The participant profile is comprised of a seven-item questionnaire that was developed to collect basic demographic data from the study participants, including age, sex, and ethnicity; and descriptive data including the age at which the participant became deaf and whether the participant has deaf parents, siblings, and/or other family members. This instrument collects demographic data used to further analyze the characteristics of the population.

Comprehension Test

The first of the two dependent variables, comprehension, is measured with a multiple choice test designed to gauge each participant's overall understanding of the heart, its function, and internal process. The test of comprehension was developed and adapted from the comprehension test from Dwyer and Lamberski (1977), and from the instructional material retrieved from *How the Heart Works* (NIH, 2011), and the *To the Heart of the Matter* (Tourville, 2002) sign language video. The Comprehension Test consisted of items that required students to have a thorough understanding of how the human heart works. Each question has four options, of which one is the correct answer. Participants were asked to select the correct answer. The language level of the test reflected a fifth grade reading level as indicated on the readability scale incorporated in the Microsoft Word software.

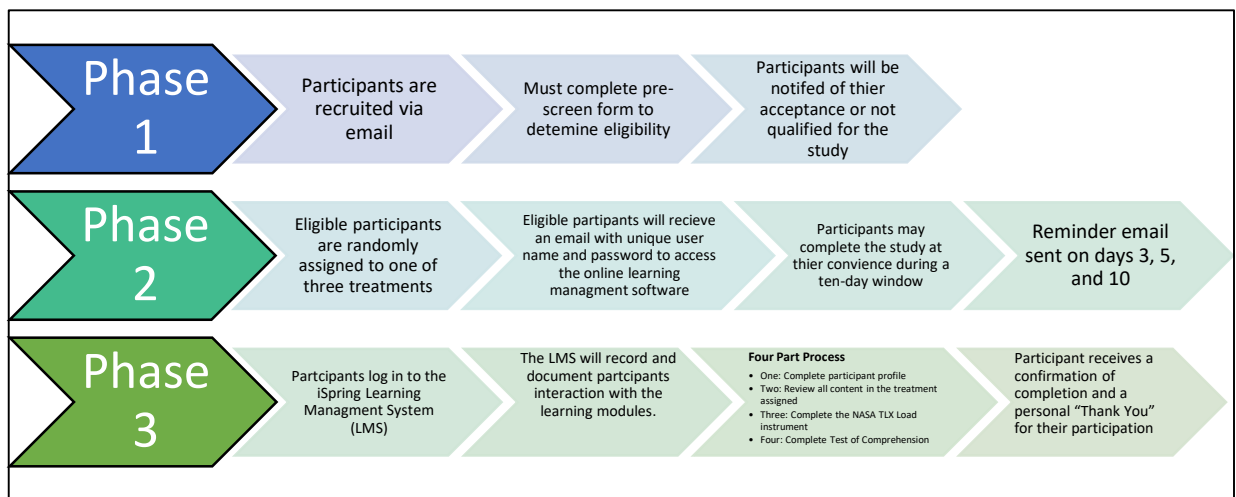
NASA-TLX

The NASA-TLX (TLX) (Hart 2006) is a multi-dimensional self-report rating tool that has been widely used to measure mental workload across a variety of fields. The TLX allows for differing measurements of workload faced by learners in a multimedia learning environment and is more sensitive than results compared to a single question measure (Windell & Wiebe, 2007). According to a study conducted by Windell & Wiebe (2007), this difference is likely due to the subjective responses on TLX subscales across varying levels and types of load, as manipulated in a study by presentation format and content difficulty. The different measures of workload are assessed across six subscales: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration. Each of these subscales are associated with a different source of workload which is rated on a 20-step bipolar scale, resulting in a score between 0 and 100. The ratings from the six subscales are factored into an equation that produces an overall weighted workload score. The current study utilized the modified version of this equation which excludes the overall weighted score. The use of the unweighted score has become commonly used due to high correlations shown between the weighted and unweighted scores (Byers, Bittner, & Hill 1989). Hart (2006) references the user-friendliness and simplicity of this modified version, referred to as the Raw TLX. The Raw TLX is derived by adding the scores from all six subscales and averaging them together. Thus, the modified TLX score was used in the current study to assess cognitive load experienced during each treatment.

Procedures

The study was completed in three distinct phases as depicted in Figure 3.2. In Phase 1, potential participants were recruited by email and were required to complete a pre-screen survey to qualify for the study. All students who completed the pre-screen survey were notified of whether or not they qualified for the study. Students who identified a major or minor as Biology or Health Sciences or whose status in college was anything other than undergraduate were notified that they did not qualify for the study.

Figure 3.2. Procedural diagram



In phase 2, participants who qualified were randomly assigned to one of three treatments. An online program was used to randomly assign each qualifying participant to one of the three treatments. Participant were emailed a notification of acceptance which contained a unique user name and password used to log in to the online learning management system to access the assigned treatment. Participants were allowed to begin the study at their convenience, but were instructed to complete it within a ten-day window of receiving log-in information. A reminder email was sent after three days and again after five days if the participant had yet to complete the study. The assigned

learning module was deactivated on the eleventh day after the notification of acceptance email was sent.

In phase 3, participants log in to the learning management system, and an introduction page opens that describes the purpose of the study, procedures to be followed during the study, instructional content and its organization, and a description of what to do at the completion of the module. An explanation of a four-part process during the study follows. Using the instructional module as a guide, the following sequence is used to direct participants through the four-part process to complete the instructional treatment:

Part One

- Complete participant profile. The participant profile is completely optional. Not all questions require an answer.

Part Two

- Review all content in the treatment assigned for the session. Requires completion.

Part Three

- Participants are instructed to complete the NASA TLX Load Instrument. All questions require an answer before proceeding.

Part Four

- Participants are instructed to complete the Test of Comprehension. All questions require an answer before completion.

After completion of the treatments, participants receive a confirmation of completion and a personal “thank you” for their participation. The participant’s online account is deactivated. Emails are sent with confirmations of the selected \$10 gift card.

Design

This study used a randomly assigned quasi-experimental design (Table 3.1). Participants were assigned to the following treatment groups: text-only (T1), picture-plus-text (P+T), and picture-plus-sign language (P+SL). Each treatment contained the same learning content titled “How the Heart Works” and was comprised of Dwyer and Lamberski (1977) print materials, *How the Heart Works* (National Institutes of Health [NIH], 2011) web resources, and the English transcript of the sign language video *To the Heart of the Matter* (Tourville, 2002). The treatment serves as the independent variable for the study. The dependent variables were learning comprehension and perceived cognitive load. Upon completion of the learning tasks, participants were given the Comprehension Test and the NASA-TLX survey. The Comprehension Test measured participants understanding of the presented instructional material. The NASA-TLX allowed participants to assign a rating to variations of cognitive load experienced while progressing through the instructional material.

Table 3.1 Research Design

	Random Assignment	Instructional Design Formats	Comprehension Test	NASA-TLX (cognitive load)
Experimental (Picture-plus-Sign Language)	R	X	O ₁	O ₂
Experimental (Picture-plus-text)	R	X	O ₁	O ₂
Control (Text-Only)	R		O ₁	O ₂

Data Analysis

This study used statistical analysis methods to reject or fail to reject the research hypotheses. Quantitative data consisted of the Comprehension Test scores, measuring learning comprehension, and the NASA-TLX scores, measuring perceived cognitive load. An analysis of variance (ANOVA) was performed on comprehension test scores and NASA-TLX scores to understand the effects of each treatment on learning comprehension and cognitive load.

Preliminary Pilot Test

Purpose

The purpose of the preliminary pilot test was twofold: (1) to test for prior knowledge and ceiling effect of the content, (2) and to review the instruments presented within the study. Prior knowledge level and ceiling effect were examined by analyzing the average score and an individual item analysis of the comprehension test given without any prior instruction. All instruments of the study were reviewed to identify ambiguous and difficult terminology that did not align succinctly with sign language.

Subjects

Eight deaf adults, four college-bound and four college-completed were selected for the pilot study. These participants are representative of the study's population in that they are deaf adults with normal intelligence, fluent in sign language and have no educational background in the content area. Participants were administered the comprehension test without any prior instruction. Upon completion of the comprehension test, participants were asked to review all instructional material alongside the comprehension test to identify any ambiguous and difficult terminology within the instructional materials that did not align completely with sign language.

Outcomes

An analysis of the comprehension test results was conducted to examine levels of prior knowledge. The average mean score for all participants (n=8) was 27% on the comprehension test. Individual item analysis of the 20-item comprehension test resulted in 3 items (items 2, 8, and 15) answered correctly by no participants; 4 items (items 10,

12, 17, and 19) answered correctly by 13% of participants; 3 items (items 5, 16, and 20) answered correctly with 25% of participants; 7 items (items 1, 6, 7, 9, 11, 13, and 14) answered correctly by 38% of the participants; and 3 items (3, 4, and 18) answered correctly by 50% of the participants. Table 3.2 shows the preliminary pilot test item and percent correct (difficulty level) per test item. Based on average participants' score results from the preliminary pilot test, prior knowledge of the instructional content does not pose a threat to internal validity. Additionally, based on the results of the pilot comprehension test scores, there is no concern for ceiling effect.

Table 3.2 Pilot Test-Item Analysis of Correct Responses

Test Item	Correct (difficulty)	Test Item	Correct (difficulty)
1	0.38	11	0.38
2	0.00	12	0.13
3	0.50	13	0.38
4	0.50	14	0.38
5	0.25	15	0.00
6	0.38	16	0.25
7	0.38	17	0.13
8	0.00	18	0.50
9	0.38	19	0.13
10	0.13	20	0.25

Items 2, 8, and 15 were excluded from the comprehension test instrument of the main study initially based on no participants answering items correctly. Further item analysis revealed that items 2, 8, and 15 as well as items 5, 10, 12, 16, 17, 19, and 20 contained ambiguous language or concepts that were difficult to translate in sign

language. There was either no distinct sign language to match the pertinent English terms verbatim or specific words would require being “finger-spelled” and would necessitate an additional vocabulary lesson to explain the term. Additionally, all items displayed a high level of difficulty ($\leq .25$ correct) and therefore were excluded from the comprehension test instrument in the main study.

CHAPTER FOUR: RESULTS

This chapter presents the analysis of data and the results of hypothesis testing. All statistical analyses were conducted using the Statistical Package for Social Sciences 23. The findings that were revealed during the data analysis can be divided into three sections: Demographic Data, Descriptive Statistics, and Primary Data Analysis. The Demographic Data section of this chapter depicts the main features of the demographic data. The Descriptive Statistics section of this chapter includes the descriptive properties of the nominal data. The Primary Analysis section includes the results of inferential statistics analysis, the results of the hypothesis testing, and the results of secondary analysis.

Demographic Data

Research participants in this study were recruited from the student population at an institution of higher learning located in eastern United States, which enrolls primarily students who are deaf. The study initially recruited 81 undergraduate students of various majors. Due to the concern for internal validity, 8 students majoring in Biology, Chemistry and Pre-med were excluded from the study. Additionally, 9 participants were excluded because of incomplete data or log-in problems within the online system. The study concluded with 64 participants with n=24 in the control text-only (T1) group, n=19 in the picture-plus-text (P+T) group, and n=21 in the picture-sign language (P+SL) group. Participants were asked to complete an optional Participant Profile survey, of which 2 participants did not complete. The survey results (n=62) collected demographic data showing a variety of education fields with the majority reporting ASL/Deaf Studies

(15%) and Psychology/Social Work (31%) as college majors. Of those participants who completed the Participant Profile surveys, 43 were female and 19 were male (Table 4.1).

Table. 4.1 *Research Participant by Gender, Academic area, and Age of hearing Loss.*

		Text-only n=24		Picture-text n=19		Picture-sign language n=21		All N=64
		n	Percent	n	Percent	n	Percent	N
Gender	Female	17	71%	13	69%	13	62%	43
	Male	6	25%	5	26%	8	38%	19
	Unanswered	1	4%	1	5%	NA		2
Academic Area	Psychology & Social Work	7	29%	5	26%	8	38%	20
	ASL & Deaf Studies	3	12%	3	16%	2	10%	8
	Education	4	17%	4	21%	5	23%	13
	Business & Communication	4	17%	5	26%	2	10%	11
	Other Areas & Undecided	4	17%	2	11%	4	19%	10
	Unanswered	2	8%	NA		NA		2
Age of Hearing loss	At Birth	15	63%	14	74%	14	66%	43
	< 4 years old	7	29%	2	10.5%	6	29%	15
	4 years old+	0	0%	2	10.5%	1	5%	3
	Unanswered	2	8%	1	5%	NA		3

Each participant is deaf, fluent in sign language, and possesses a moderately-severe to profound hearing loss. Of the completed survey questions, 71% of participants were identified with a hearing loss at birth, while 24% were identified before school age. Further, 39% of the participants had at least one deaf parent, while 28% had no other deaf person in their immediate family.

Descriptive Statistics

This section includes the descriptive statistics of the data gathered for the Comprehension test and the NASA-TLX, as well as the average time spent on each treatment. Comprehension was measured by the comprehension test adapted from Dwyer and Lamberski (1977). The purpose of the comprehension test is to measure understanding of the learning material presented on the heart and its function upon completion of the instructional lesson. The test is comprised of 20 multiple-choice items. Based on the preliminary pilot test analysis, items that were identified as having a high level of difficulty due to the ambiguous language and difficulty to translate were not assessed. Ten remaining items were scored at 10 points each for a total of 100 possible points, with a Kuder-Richardson-20 (KR-20) reliability coefficient of .49.

The performance mean scores and standard deviation of the Comprehension test across the three instructional groups are shown in Table 4.2. The mean score for the text-only treatment group was 30.43 with a standard deviation of 21.57, with 16.7% of research participants scoring 60 or higher. The mean score for the picture-plus-text treatment group was 50.53 with a standard deviation of 9.7, with 31.6% of research participants scoring 60 or higher. The mean score for the picture-plus-sign language treatment group was 42.38 with a standard deviation of 22.34, with 23.8% of research participants scoring 60 or higher. All three mean scores were relatively low and display low levels of comprehension for all three treatments.

Table 4.2 Mean scores of Comprehension Test by Treatment

Instructional Format	n	Mean	SD	Test Items	Min. score	Max. score
Text-only	24	30.42	21.57	10	10	90
Picture-text	19	50.53	9.70	10	30	70
Picture-sign language	21	42.38	22.34	10	0	80
Total All	64	40.32	20.62			

This study used the NASA- TLX to measure cognitive of participants for each treatment group. The NASA-TLX consists of subjective ratings across six sub-domains resulting in an overall average score ranging from 0-100. The mean scores and standard deviation of the NASA-TLX across the three instructional treatments are shown in Table 4.3. The mean score for cognitive load experienced by the text-only treatment group was 56.63 with a standard deviation of 10.62. The mean score for cognitive load experienced by the picture-plus-text treatment group was 37.21 with a standard deviation of 7.08. The mean score for cognitive load experienced by the picture-plus-sign language treatment group was 40.90 with a standard deviation of 8.85. The text only treatment group reported the highest level of cognitive load.

Table 4.3 Mean scores for NASA-TLX by Treatment

Instructional Formats	n	Mean	SD
Text-only	24	56.63	10.62
Picture-text	19	37.21	7.08
Picture-sign language	21	40.90	8.85

Usage and viewing details for each treatment group were tracked using the online learning management system. Time tracking was not available for individual slides, but total time for each instructional lesson per participant was provided. Average time spent per treatment group are shown in Table 4.4. This provides some data regarding the time spent on learning materials.

Table 4.4 Presentation Time by Treatment

Treatment	Number of Slides	Average Total Time	Average Number of Slides Repeated
Text-only	12	15:20	7
Picture-text	16	19:50	4
Picture-sign language	22	16:25	12

The average number of slides repeated within the text-only treatment is more than half (7 out of 12) of the total slides for the treatment. Similarly, the average number of slides repeated within the picture plus sign language treatment is more than half (12 out of 22) the total number of slides for the treatment. While the picture plus text treatment resulted in only a fourth of the slides repeated (4 out of 16) on average, within the treatment.

The average time expected to complete each treatment was 30 - 45 minutes. Average total times for all three treatments were below the expected average time. The average total time spent within the text-only treatment was the shortest time of the three treatments, with 15 minutes and 20 seconds. The average time spent within the picture plus sign language treatment was 16 minutes and 25 seconds. While the picture plus text treatment produced the highest average time spent within the treatment, with 19 minutes and 50 seconds. Average time spent within each treatment was lower than the expected time to fully comprehend instructional material within the treatment.

Primary Data Analysis

In this section, the primary hypotheses of this study was tested using a one-way ANOVA, with a Tukey HSD post hoc analysis. Six research hypotheses were examined related to learning comprehension and cognitive load. Hypotheses 1, 2, and 3 addresses learning comprehension for the three treatment groups. Hypothesis 4, 5 and 6 addresses cognitive load for the three treatment groups.

H1: There will be a significant difference in Comprehension Test scores with a higher mean test score for the picture-plus-text treatment when compared to the mean test score for the text-only treatment.

H2: There will be a significant difference in Comprehension Test scores with a higher mean test score for the picture-plus-sign language treatment when compared to the mean test score for the text-only treatment.

H3: There will be a significant difference in Comprehension Test scores with a higher mean test score for the picture-plus-sign language treatment when compared to the mean test score for the picture-plus-text treatment.

H4: The text-only treatment will produce significantly higher cognitive load than the picture-plus-sign language treatment.

H5: The text-only treatment will produce significantly higher cognitive load than the picture-plus-text treatment.

H6: There will be a significantly higher cognitive load for the picture-plus-text treatment when compared to the picture-plus- sign language treatment.

Learning Comprehension

A one-way between subject ANOVA was conducted to compare the effects of the text-only, picture-plus-text, and picture-plus-sign language treatments on comprehension test scores. Results are noted in Table 4.5. With a p value $<.05$, there was significant effect found for the three treatments [$F(2,61) = 6.03$, $p=.004$].

Table 4.5 One Way ANOVA for Comprehension Test Scores

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4422.227	2	2211.114	6.029	.004
Within Groups	22371.523	61	366.746		
Total	26793.750	63			

Results of the post hoc comparison using the Tukey HSD test, noted in Table 4.6, indicated that the mean difference of 20.11 between picture-plus-text treatment ($M=50.53$, $SD=9.7$) was significantly higher than the text-only treatment ($M=30.42$, $SD=21.56$) on comprehension test scores. However, there was no significant difference between picture-plus-sign language treatment and the text-only treatment or the picture-plus-text treatment and picture-plus-sign language treatment on comprehension test scores.

Table 4.6 Tukey HSD Post-Hoc for Comprehension Test Score

Study Group		Mean Difference	Std. Error	Sig.
Text-Only	Picture+Sign Language	-11.964	5.722	.100
	Picture+Text	-20.110*	5.881	.003
Picture+Sign Language	Text-Only	11.964	5.722	.100
	Picture+Text	-8.145	6.064	.377
Picture+Text	Text-Only	20.110*	5.881	.003
	Picture+Sign Language	8.145	6.064	.377

*denotes significance

As demonstrated by Tukey HSD test, a significant difference existed between the text-only treatment and picture-plus-text treatment on mean comprehension test scores. The mean for comprehension test scores for the picture-plus-text (N=19, M=50.53, SD=9.70) treatment is significantly higher than the text-only (N=24, M=30.42, SD=21.57) treatment. Based on these findings, it can be concluded with 95% confidence that comprehension scores of the picture-plus-text group performed significantly better than the text-only group on the comprehension test (Hypothesis 1). The post-hoc analysis conducted determined no significant difference existed between the picture-plus-sign language (N=21, M=42.38, SD 22.34) treatment and the text-only (N=24, M=30.42, SD=21.57) treatment on mean comprehension test scores (Hypothesis 2). Likewise, the post-hoc analysis conducted determined no significant difference existed between the picture-plus-sign language (N=21, M=42.38, SD 22.34) treatment and the picture-plus-text (N=19, M=50.53, SD=9.70) treatment (Hypothesis 3).

Cognitive load

A one-way between subject ANOVA was conducted to compare the effects of the text-only, picture-plus-text, and picture-plus-sign language treatments on cognitive load noted by NASA-TLX scores. Results are reported in Table 4.7. With a value $p < .05$, there was significant effect found for the three treatments [$F(2,61) = 28.42$, $p = .00$].

Table 4.7 One Way ANOVA for NASA-TLX scores

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4716.767	2	2358.383	28.417	.000
Within Groups	5062.592	61	82.993		
Total	9779.359	63			

Results of a post hoc comparison using Tukey HSD test, reported in Table 4.8, indicated that the mean difference of 19.41 for the text-only treatment ($M=56.63$, $SD=10.62$) was significantly higher than the picture-plus-text treatment ($M=37.21$, $SD=7.08$) on cognitive load. Likewise, the mean difference of 15.72 between the text-only treatment was significantly higher than the picture-plus-sign language ($M=40.90$, $SD=8.85$) treatment on cognitive load. It can be concluded with 95% confidence level that the difference between treatments and cognitive load are due to the type of treatment. However, there was no significant difference between the picture-plus-sign language treatment and the picture-plus-text treatment on cognitive load.

Table 4.8 Tukey HSD Post-Hoc for NASA-TLX scores

		Mean Difference		
Study Group		(I-J)	Std. Error	Sig.
Text-Only	Picture+SignLanguage	15.72024*	2.72215	.000
	Picture+Text	19.41447*	2.79752	.000
Picture+SignLanguage	Text-Only	-15.72024*	2.72215	.000
	Picture+Text	3.69424	2.88446	.411
Picture+Text	Text-Only	-19.41447*	2.79752	.000
	Picture+SignLanguage	-3.69424	2.88446	.411

*denotes significance

As demonstrated by the Tukey HSD post-hoc analysis, the difference that exists between the text-only (n=24, M=56.63, SD=10.62) treatment is significantly higher than the picture-plus-sign language treatment (n=21, M=40.90, SD=8.85) on cognitive load. The mean scores of the NASA-TLX for the text-only treatment displays significantly higher cognitive load than the picture-plus-sign language treatment (Hypothesis 4). The post-hoc analysis conducted shows a statistically significant difference between the text-only (n=24, M=56.63, SD=10.62) treatment and picture-plus-text (n=19, M=37.21, SD=7.08) treatment on cognitive load. The mean scores of the NASA-TLX for the text-only treatment displays significantly higher cognitive load than the picture-plus-text treatment (Hypothesis 5). However, the post-hoc analysis conducted determined no significant difference existed between the picture-plus-text (n=19, M=37.21, SD=7.08) treatment and the picture-plus-sign language (n=21, M=40.90, SD=8.85) treatment on cognitive load (Hypothesis 6).

Secondary Analysis

A secondary analysis was performed to determine if a linear relationship exist between variables, comprehension and cognitive load, among treatment groups. A Pearson correlation coefficient was conducted to evaluate the relationship between cognitive load and learning comprehension for the text only, picture-plus-text, and picture-plus-sign language treatments. There was significant evidence showing a positive linear association between cognitive load and comprehension for the picture-plus-sign language treatment, $r(21) = .494$, $p < .05$, as noted in Table 4.9.

Table 4.9 Pearson Correlation by Treatment

		Comprehension Test Score
Text only	Cognitive Load	-.297
	Sig. (2-tailed)	.158
Picture plus text	Cognitive Load	-.244
	Sig. (2-tailed)	.314
Picture plus sign language	Cognitive Load	.494*
	Sig. (2-tailed)	.023

*denotes significance

Higher cognitive load level is correlated to higher level of comprehension for the picture-plus-sign language instructional treatment. However, there was no statistical correlation identified in the relationship between cognitive load and comprehension for the text-only treatment or the picture-plus-text treatment groups.

Summary

Primary data analysis was focused around two dependent variables; learning comprehension and cognitive load. A post-hoc comparison showed a statistically significant difference between the mean comprehension test scores for the text-only treatment and the picture-plus-text treatment, with the picture-plus-text group performing significantly higher than the text-only group on comprehension tests. However, there was no statistically significant difference between the picture-plus-text treatment and the picture-plus-sign language treatments on comprehension test scores. Additionally, there was no significant difference between the text-only treatment and the picture-plus-sign language treatment on comprehension test scores.

The comparison of cognitive load was indicated by the NASA-TLX mean scores. The text-only treatment displayed the highest mean TLX score on cognitive load. A significant difference was found with the text-only treatment group displaying higher cognitive load than the picture-plus-sign language treatment group on the NASA-TLX. Additionally, a significantly higher difference in cognitive load was found for the text-only treatment in comparison to the picture-plus-text treatment on the NASA-TLX. However, there was no statistical significant difference in cognitive load between picture-plus-text treatment and the picture-plus-sign language treatment on the NASA-TLX.

CHAPTER FIVE: DISCUSSION AND CONCLUSION

The primary purpose of this study was to examine and analyze the learning benefit of multimedia instruction compared to text-only instruction on comprehension and cognitive load among students who are deaf. The theoretical framework used in this study was based on prior research examining the use of multimedia instruction with students who are deaf, as well as the principles of Cognitive Load Theory.

Prior research examining the effectiveness of various instructional materials for deaf students showed that pictorial formats, along with simple or brief text, helped students to learn and recall more information and proved beneficial in content comprehension (Reynolds & Rosen, 1973; Reynolds & Booher, 1980; Robbins, 1983; Wilson & Hyde, 1997; Walker, Munro, & Richards, 1998). Other research focusing on the application of multiple media formats also provided favorable results in the comprehension of content when accompanied with a variety of visual modalities, visual media, and adjunct visual aids (Kelly, 1998; Dowaliby & Lang, 1999; Horney & Anderson-Inman, 1999; Loeterman et al., 2002; Lang & Steely, 2003; Gentry et al., 2005; Yoon & Kim, 2011). This study specifically sought to address whether a multimedia format would produce greater learning gains and lower cognitive load than a single media text-only format.

Cognitive Load Theory (CLT) was explicitly developed as a theory to facilitate instructional design based on knowledge of the human cognitive architecture (Sweller, Ayres, & Kalyuga, 2011). CLT, when applied appropriately, can ensure the full utilization of working memory and aid in designing materials that compensate for cognitive processes, thereby reducing cognitive load and improving learning outcomes

(Sweller et al., 2011). CLT provides guiding principles for designing multimedia instruction that adheres to students who have differing knowledge levels, cognitive abilities, and working memory characteristics (Sweller, 2004). Students who are deaf typically possess such differences, along with a lower than average reading comprehension level due to the complexities of learning to process a phonetically dependent language. Thus, the development of effective multimedia instruction for students who are deaf is paramount to educators of the deaf.

This study involved three treatment groups: two comprised of multimedia formats, picture-plus-text and picture-plus-sign language, and a control single media format of text-only. All treatments were transferred into an online learning module that could be accessed anywhere and from different technology devices. The picture-plus-text group received instruction in both text and pictures presented simultaneously. The picture-plus-sign language group received instruction in sign language and pictures simultaneously. The text-only group was presented with material containing only text. All three groups were required to complete the NASA-TLX, a self-report cognitive load rating tool, immediately following the instruction. The NASA-TLX allowed participants to rate their level of cognitive load as a result of the instructional treatment. Following the NASA-TLX, students received a comprehension test. The comprehension test measured the participant level of understanding of the learning material presented within the instructional treatment.

Discussion of Results

The following discussion is based on the results of this study. First, a discussion of the three hypotheses related to comprehension test scores for text-only, picture-plus-text, and picture-plus-sign language treatments will be presented. Second, a discussion of the three hypotheses concerning the impact of cognitive load experienced between the three treatments; text-only, picture-plus-text, and picture-plus-sign language will be presented.

Discussion of Results on Comprehension by Hypothesis

Hypothesis 1: *There will be a significant difference in Comprehension Test scores with a higher mean test score for the picture-plus-text treatment when compared to the mean test score for the text-only treatment.*

Based on the statistical analysis of the data on learning comprehension, there was a statistical difference found for Hypothesis 1. Mean test scores for the picture-plus-text treatment were significantly higher than the text-only treatment. The mean comprehension test score for the picture-plus-text treatment was 50.53, while the mean comprehension test score for the text only treatment was 30.42.

These findings are consistent with previous studies conducted with deaf participants, Reynolds & Rosen (1973), Reynolds & Booher (1980), Diebold & Waldron (1988) and Gentry, Chinn, & Moulton (2005) who also found that an instructional treatment composed of picture and text combination produced significantly higher results

in comprehension than a text-only instructional treatment. The higher level of comprehension can be attributed to the explicitness and clarity of a pictorial presentation that can be effective with deaf or linguistically deficient students (Reynold et al., 1973). Pictorial representations provide obvious and clear explanations that can be easily understood visually, with no requirement of the learner to do additional linguistic decoding.

Pictorial and text combination format may be equally as beneficial for deaf students as for hearing peers. Past studies with hearing subjects have resulted in greater learning gains for picture and text instruction when compared to a single modality text instruction (Mayer & Anderson, 1991; Mayer, Heiser, & Lonn, 2001; Mayer & Moreno, 2002, 2003; Tabbers, Martens, & Van Merriënboer, 2004; Mayer, 2005, 2009b;). The present study, conducted with deaf subjects, produced similar results. With such consistent results, it is concluded that the use of pictorial information integrated with text, can not only provide information which is supplementary and redundant to the text, but also can enhance student achievement and comprehension for both deaf and hearing students.

Hypothesis 2: *There will be a significant difference in Comprehension Test scores with a higher mean test score for the picture-plus-sign language treatment when compared to the mean test score for the text-only treatment.*

Unexpectedly, there was no statistical difference found for Hypothesis #2. Although there was no significant difference found, participants of the picture-plus-sign language treatment mean was higher on the comprehension test with a mean score of

42.38, than the mean score of 30.42 found in the text-only treatment. Several reasons could be attributed to these results.

First, the results may be attributed to split attention effect. The split-attention effect occurs when the learner is required to split their attention between and mentally integrate different sources of information displayed at the same time (Sweller, Ayres, & Kalyuga, 2011). The picture-plus sign language treatment placed sign language video and a related picture, in separate locations on the same slide. Therefore, the picture-plus-sign language treatment in this study may have divided learner attention causing a split between watching the signed videos and reviewing the corresponding pictures. The multiple representations of information may cause the learner to decide which media to attend to, when, and for how long. This process of inconsistent manipulation, where learners can make the individual choice of how long and whether or not to attend to instructional materials may impact the effectiveness of the learning process. Instructional treatments that adheres to this split-attention effect, may replace the multiple sources of information with a single integrated source (Sweller et al., 2011).

The second reason for not obtaining a significantly higher score could be attributed to the difference that exists between the format used to test content mastery and the format used to teach the content. The picture-plus-sign language treatment is comprised of pictures and sign language. There is no text displayed throughout the entirety of the instructional treatment. However, the response instrument, the comprehension test, is comprised of only text. Therefore, it may drastically impact the learner's ability to transfer the knowledge gained from the content, and encode that knowledge to match the format found on the response instrument.

Hypothesis 3: *There will be a significant difference in Comprehension Test scores with a higher mean test score for the picture-plus-sign language treatment when compared to the mean test score for the picture-plus-text treatment.*

The mean test scores for the picture-plus-sign language treatment was not significantly higher than the mean test scores for the picture-plus-text treatments as predicted in Hypothesis 3. This finding was surprising because it defied the assumption that learners who are deaf and use sign language in their everyday communication would perform significantly better when instruction is given in sign language.

There are several potential reason for these results. The first reason that could have caused the picture-plus-sign language treatment to not produce a higher mean score than the picture-plus-text treatment deals with how sign language is processed in working memory. Text is a language dependent upon verbal processing and phonetic awareness and is processed within the phonological loop of working memory (Baddeley & Hitch, 1974). Sign language is linguistic in nature but is a language dependent upon visual cues, gestures, movements, and handshapes, and may be processed in the visio-spatial sketchpad of working memory. According to Baddeley and Hitch (1974), the visuo-spatial sketchpad is responsible for maintaining and manipulating visual or spatial information. Therefore, it is possible that sign language is processed in the same part of the working memory as pictures and other visual information. Thus, a treatment comprised of both sign language and pictures may create an inefficient use of working memory, causing higher levels of cognitive load. Or perhaps a better way of looking at the results would be to focus on the relative strength of pictures and its significance in the learning process (Gentry et al., 2005).

A second possible reason for the comprehension test scores of picture-plus-sign language treatment not being statistically higher than the mean comprehension test scores for the picture-plus-text treatments could be attributed to participant interest and motivation in the study. All students were compensated with a \$10 gift card of their choice upon completion of the study. However, as an effect of being an online instructional module, there was no “face to face” interaction throughout the entire process. Therefore, although participants were compensated for their time and effort, there was no way to gauge genuine interest and motivation of completing all parts of the instructional treatments as directed.

A third reason that could have caused the lower comprehension mean scores in the picture-plus-sign language treatment is the duration of time spent within the instructional treatment. Given the nature of the topic, the average time utilized to complete the instructional material was not sufficient to learn the concept while completely attending to both the videos and the pictures effectively. The researcher’s estimated completion time to attend to all instructional material within the treatment was 35-45 minutes. The average time spent by participants within the treatment was 16.5 minutes. The average time per treatment is greatly less than the time anticipated by the researcher.

Another reason that could have caused the rejection of both Hypothesis 2 and Hypothesis 3 is the low reliability of the comprehension test. Test item analysis identified 10 test items that were omitted from the study due to difficulty level and language ambiguity of the test items. As a result, the remaining 10 items on the comprehension test

produced a Kuder-Richardson-20 (KR-20) reliability coefficient of .49, which is lower than the generally accepted reliability score of .65 for making decisions about a group (Fribie, 1988).

Discussion of Cognitive Load Results

The mean NASA-TLX scores were significantly higher for the text-only treatment when compared to both the picture-plus-text and the picture-plus-sign language treatments. Therefore, both Hypothesis 4 and Hypothesis 5 were supported. However, Hypothesis 6 was not supported, as the NASA-TLX score for the picture-plus-text was not significantly different from the picture-plus-sign language treatment. Additionally, the NASA-TLX mean scores for the picture-plus-sign language was unexpectedly higher than the mean scores of picture-plus-text treatment on cognitive load. As a result of this study, the picture-plus-sign language produced a higher level of cognitive load than the picture-plus-text treatment. The text-only treatment produced the highest cognitive load among all three treatments.

The text only treatment proved to be ineffective for learning comprehension with students who are deaf despite the fact that it was designed on a fifth -grade reading level. Additionally, the text only treatment was associated with the highest level of cognitive load. According to Diebold et al. (1988), instructional formats that rely heavily on linguistically dependent text to convey information are of limited value to the deaf learner, and therefore may reduce learning comprehension and produce higher cognitive load.

The picture-plus-sign language treatment showed an advantage over the text only treatment for both comprehension and cognitive load. While the total amount of cognitive load for the picture-plus-sign language treatment was not significant, the mean score was less than the mean score for the text only treatment. The design feature of the picture-plus-sign language treatment required the sign language video be displayed adjacent the corresponding pictures. Consequently, the learners were required to integrate multiple sources of information that were separate in space and time. This additional processing may have caused extraneous load and hindered the learning process.

In summary, the picture-plus-text treatment proved to be the most effective instructional format with significantly higher scores on the comprehension test. Likewise, the picture-plus-text treatment produced the lowest level of cognitive load evidenced by the NASA-TLX mean scores. An instructional treatment comprised of text and the visual representation provided by pictures delivered effective instruction to deaf learners. The instructional benefit of pictures as a visual resource fostered significantly better results on comprehension and cognitive load. As instruction is designed, it is important to note that the allocation of visual resources requires specific attention, because it strongly affects the learner's ability to understand, analyze and synthesize the informational content provided by these resources (Ghinea and Thomas 1998).

Limitations of the Study

There were five limitations that must be considered as results are interpreted for this study. These include the reliability of the comprehension test, the generalization to the population as a whole, the interest and motivation of participants, and other unknown but relevant variables that may have impacted results.

Limitations of the Study

1. All of the participants in this study were enrolled in an undergraduate program at a university for the deaf in southeastern United States. Therefore, results should be generalized with caution. It is assumed that different populations may lead to different conclusions.
2. Due to the analysis that took place as part of the pilot study 10 test items were excluded due to language difficulty to translate directly corresponded with sign language. Only 10 test items remained were used for the study. Thus, the low reliability of comprehension tests should be considered when interpreting the results.
3. Participants in this study majored in areas other than Biology. It is assumed that their prior knowledge of the biology domain was relatively low. Thus, it is expected that they may have had limited interests in context about the human heart. This may have led to participants rushing through the instructional content without regard to truly learning and comprehending the information presented.
4. The study was administered entirely online. Therefore, there was no

“face to face” interaction with participants to gauge the effectiveness of instruction. Participants were given the option to repeat slides or elements of the slide as many times as needed, but most only completed the required one-time run though.

5. Due to the nature of an online study, conditions of the learning environment is unknown. There is no known consistency in the type of device used, where learning took place, or other resources used.
6. The present study does not measure other variables that may have affected the results found in comprehension and cognitive load, such as motivation and self-efficacy with online self-paced instruction. The degree to which these variables impacted results is unknown.

Implications for Future Research

This study examined the impacts of multimedia on comprehension and cognitive load for students who are deaf. A significant difference was found with the picture-plus-text treatment on comprehension test scores, but not for the picture-plus-sign language treatment. This study produced an unexpectedly higher load in the picture-plus-sign language treatment than the picture-plus-text, although it was not significantly higher. Based on the results and limitations of this study, future research recommendations are presented.

For future research within the same population, it would be beneficial to compare the effects of comprehension and cognitive load under both a system-controlled and a self-paced sign language condition. Additionally, control of the learning environment where the study takes place is another consideration for future research. This environmental control would remove concern for multiple types of devices and unknown external factors that may impact learning or cognitive load. These additional constraints may produce more reliable results of comprehension levels among treatments and may control for concerns related to duration of time spent with the learning materials.

Another consideration for further research is to compare the learning effects of a single format treatment where both the instructional materials and the comprehension test is comprised of the same media format. Thus if the instructional treatment consisted of sign language only, the comprehension test would also be delivered in a sign language only format. Likewise, a pictorial instructional format would coincide with a pictorial comprehension test. This would alleviate the concern for the way the content is taught matching the way it is tested. As noted as one of the area of limitations in the study, the present study does not measure other possibly relevant variables that may have affected comprehension and cognitive load. Further research could include an examination of other variables such as motivation and effort, self-efficacy with online or self-paced instruction, and user interaction with the learning task. Motivation, effort, and self-efficacy are all subjective measures that could be used to examine results found in comprehension and cognitive load. User interaction with the learning material may be examined using video or eye tracking devices, allowing the researcher to gather

information using objective measures. By adding these variables and measures, the study would produce more comprehensive results.

Implication for Practice

Results of this study provides some practical implication for educators who work with students who are deaf. While there is still more to be explored, this study validates the need to consider limited use of text-only material within the instructional environment. The single modality format of text-only material may pose unnecessary cognitive load for a deaf learner. Thereby, producing low levels of comprehension of the material to be learned.

Conversely, this study supports the utilization of the multimedia format comprised of both pictures and text for learning novel material. While the picture plus text format may not be the most widely used, especially compared to a sign language format, it is evident that there are some viable benefits when used in the learning environment. This study provides a basis for educators of the deaf to explore the instructional impact of pictures plus text material. The results may be more significant than the most commonly used format of picture plus sign language.

Summary and Conclusion

Two research questions framed the present study. (1) Is there a difference in learning comprehension of deaf students who are exposed to multimedia formats of picture-plus-text and pictures-plus-sign language when compared to a single mode format of text-only? (2) Does either the picture-plus-text or pictures-plus-sign language format

produce significantly less cognitive load when compared to the text-only format for students who are deaf? The findings of this study suggest that multimedia design treatments will produce significantly higher comprehension than the use of a text-only single media format among students who are deaf. This result was specifically found in the picture-plus-text treatment. It was hypothesized that the sign language condition would produce the greatest comprehension gain due to students use of sign language for everyday communication. However, the evidence of this study produced results to the contrary. There was no significant difference found for the picture-plus-sign language treatment. This was unexpected.

In conclusion, it is important to note that the systematic application of a pictorial based multimedia design is the least studied and most overlooked medium of instruction for deaf learners (Diebold & Waldron 1988). Gentry et al. (2005) assert that instructional material should offer a multilingual approach to teaching content to students who are deaf. For example, students may read information via text media, can acquire additional information from pictures, and receive still more instructional supports via sign language. This process may help bridge gaps between text and signed communications. Implications for deaf education may regard multimedia, specifically the combination of text and pictures, as an effective tool for content comprehension as long as instructional materials are systematically designed to appeal to the processing strengths and supplements any linguistic deficits of the deaf or hard of hearing learner.

APPENDIX A: MATRIX OF RESEARCH STUDIES

Table A1: Multimedia design Studies with Deaf Populations

Multimedia Design	Author/Study	Subjects	Dependent Variables/ Measurements	Methods/Treatments	Results
Pictures	Reynolds & Rosen, 1973	Exp #1: n=52	Comprehension and Retention with a 1 day delay	Three printed instructional formats: 1. Textbook narrative	Exp #1: Significantly higher scores for pictorial format ($p<.05$)
		Exp #2: n=94	Comprehension and Retention with a 13 day delay	2. Text, drawing, learning objective, self-paced 3. Pictorial displays with labels and descriptive phrases	Exp #2: ($p<.02$) Between Exp 1 and Exp 2 significant at ($p<.001$) decline in retention for 13 day post-test
Pictures	Reynolds & Booher, 1980	n=56	Task completion/error rate	Four treatments: 1. All pictorial 2. All Verbal 3. High pictorial-low verbal 4. High verbal-low pictorial	All pictorial shortage mean task completion time/high error rate High pictorial-low verbal statistically significant lowest mean error rate/second shortest task completion time

Table A1 (Continued)

Pictures	Diebold & Waldron, 1998	n=60	Comprehension; Pre-test/post-test Hypothesis; better comprehension with simplified text and pictorial information	Four instructional formats 1. Text 2. Simplified text 3. Simplified text/labeled diagram 4. Labeled diagram	simplified text format yielded the highest mean gain score labeled diagram was the only format to yield significant comprehension gains (p<.05)
Instructional Program	Walker, Munro, & Richards, 1998	n=60	Pre-test/post-test measuring literal and inferential reading	Two experimental groups and two Control groups 1. Instructional program with pictorial material and written text instructed by Researcher 2. Instructional program with pictorial material and written text instructed by regular teachers 3. Conventional reading comprehension program 4. No instructional program	Group 1 showed an improvement in inferential comprehension (t=5.1), but not in literal comprehension Group two improved in literal (t=6.6) and inferential comprehension (t=4.2), Group three showing improvement only in literal reading (t=2.7) Group four showing no improvement

Table A1 (Continued)

Movies	Kelly, 1998	Single-subject design	(1) Comprehension of passive voice sentences, (2) comprehension of passive voice control sentences, (3) comprehension of relative clause sentences, and (4) comprehension of relative clause control sentences.	10 silent movie videos	
Multiple Medias	Dowaliby & Lang, 1999	n=144	Retention; post-test	Five instructional conditions 1. Text only 2. Text and content movies 3. Text and sign movies 4. Text and adjunct questions 5. Full condition (all)	adjunct question and full condition yielded significantly greater post-test performance than the text-only, content movie, and sign movie conditions (all $ps < .05$),

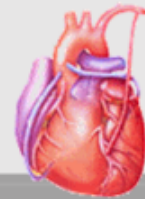
Table A1 (Continued)

Multiple Medias	Gentry, Chinn, & Moulton, 2005	n=25	Repeated measure; improving reading skills transfer/recall	Four multimedia formats 1. Print only 2. Print plus pictures 3. Print plus digital video of sign language 4. Print plus pictures plus digital video of sign language	strongest when stories were presented in the print plus pictures format no statically significant difference between the print plus pictures when compared to the print plus pictures plus sign language
Multiple medias	Nikolarazi, Vekiri, & Easterbrooks, (2013)	n=8	reading comprehension	Multimedia Software includes electronic texts, videos, pictures, sign language, and concept maps	

APPENDIX B: INSTRUCTIONAL MODULE PICTURE-PLUS-TEXT (P+T)

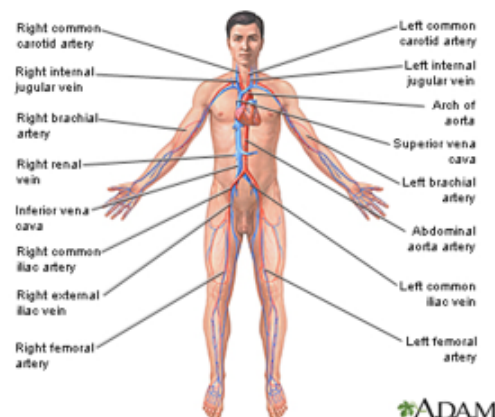
TREATMENT

How The Heart Works



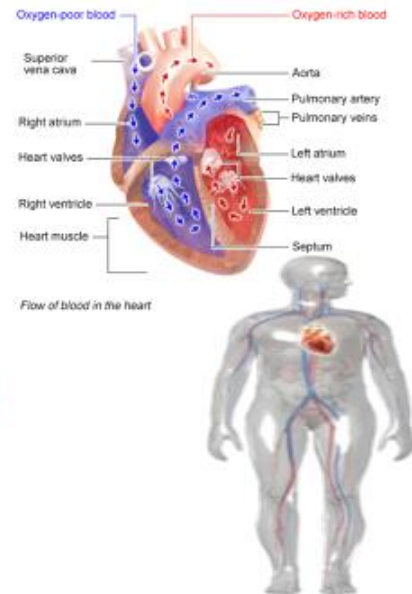
THE CARDIOVASCULAR SYSTEM

- This presentation will focus on the cardiovascular system, one of twelve or so major organ systems in your body.
- The cardiovascular system is the primary transportation system in your body. When glucose (sugar) travels around your body from your liver to your toe, for example, it is your cardiovascular system that is responsible. When oxygen travels from your heart to your brain, it is the cardiovascular system that's responsible for that also.
- **The two basic components of the cardiovascular system are:**
 - (1) **the heart, which is the center of your circulatory system.**
 - (2) **miles and miles of hollow tubes that carry blood called blood vessels, veins, or arteries.**
- We are going to focus primarily on the heart.



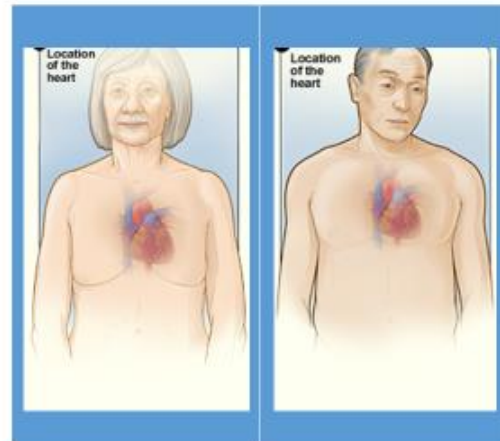
What is the Heart

- Your heart is a muscular organ that pumps blood to your body.
- A normal, healthy, heart is about the size of a grapefruit.
- The heart has a couple of different primary functions.
 - ↳ It receives blood that is **de-oxygenated** or **oxygen-poor** (has no oxygen in it),
 - ↳ The heart will then **send that blood up to your lungs** so it can fill up with oxygen. This **oxygen-rich blood will return to the heart** from the lungs.
 - ↳ The heart then **sends this oxygenated blood out** to every single tissue in the body.



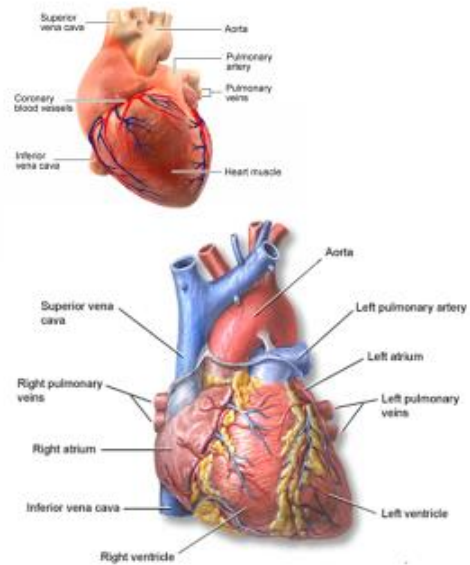
The Beating Heart

- **The heart is completely made up of living cells known as cardiovascular muscle cells.**
- These cells are unique because they are found nowhere else in the body.
- **Cardiovascular muscle cells have the ability to shorten or contract,** causing the muscular walls of the heart to beat, or contract, pumping blood to all parts of your body.



Your Heart's Exterior

- The external structures of the heart is made of cardiovascular muscle cells, and includes other arteries and veins.
- **Arteries** carry blood away from the heart
- While **veins** carry blood into the heart.
- Vessels that are colored blue indicate the transport of blood relatively low in oxygen and high in carbon dioxide.
- Vessels that are colored red indicate the transport of blood relatively high in oxygen and low in carbon dioxide



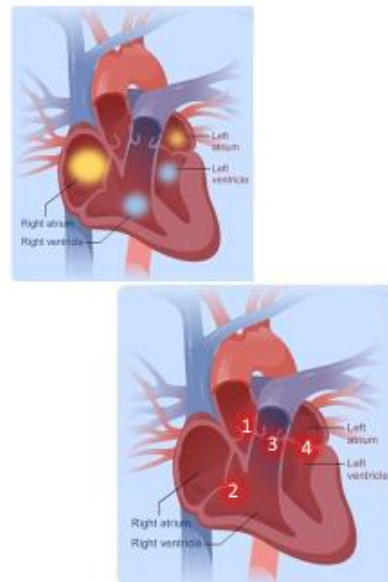
The Inside of the Heart

Heart Chambers

- The heart is divided into four chambers. The two upper chambers of your heart are called the right atria and the left atria. They receive and collect blood.
- The two lower chambers of your heart are called the right ventricle and the left ventricle. The ventricles pump blood out of your heart to other parts of your body.

Heart Valves

- Throughout the heart, are 4 little one-way stop and go systems, called valves, that are essential for ensuring that blood travels from one direction. Valves allows blood to pass through the chambers and into your arteries without backing up or flowing backward
- Your heart has four valves.
- (1) aortic valve,
- (2) the tricuspid valve,
- (3) the pulmonary valve,
- (4) and the mitral (or bicuspid) valve.



INSIDE your Heart - **RIGHT SIDE**

- The pumping cycle begins when deoxygenated blood from your body that is low in oxygen fill your heart's right atrium
- When the right atrium is full with blood, it contracts, the **tricuspid valve opens**, and blood is pumped into the right ventricle.
- When the right ventricle is full with blood, the **tricuspid valve closes**. This prevents blood from flowing back into the right atrium.
- Full with blood, your heart's right ventricle contracts. The **pulmonary valve opens** and blood is pumped into your pulmonary artery and on to your lungs.
- The **pulmonary valve quickly closes** to prevent blood from flowing back into the right ventricle.
- The **pulmonary artery** will carry blood up to the lungs, where the blood will move around in lung tissue and become filled with oxygen. This is also called the **pulmonary loop**.



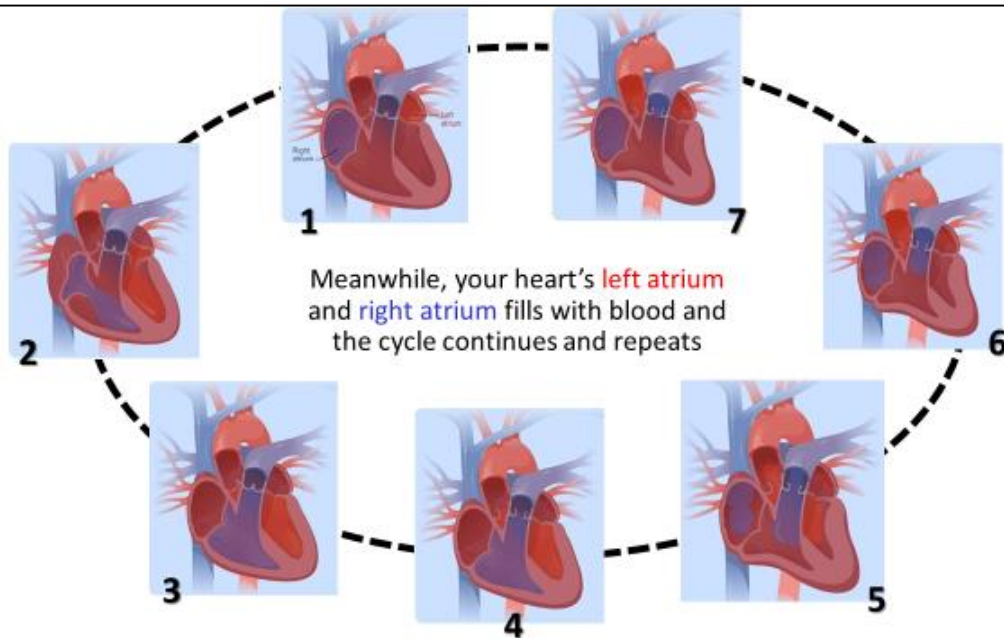
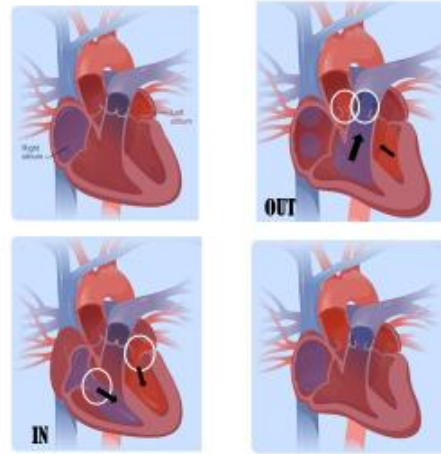
INSIDE your Heart - **LEFT SIDE**

- After blood spends a few moments in the lungs, it returns to the heart, **except on the LEFT side**, and it enters the small upper left atrium. This blood is full of oxygen.
- Your heart's left atrium contracts, the **mitral valve (or bicuspid valve) opens**, and blood is pumped into the left ventricle.
- This occurs at the same time a new contraction is taking place in your heart's **RIGHT** atrium.
- When your heart's left ventricle is full with blood, the **mitral valve closes**. This prevents blood from flowing back into the left atrium.
- Your heart's left ventricle contracts and the **aortic valve opens**. The contraction pumps **oxygen-rich blood** into your aorta and on to the rest of your body
- The **aortic valve quickly closes** to prevent blood from flowing back into the left ventricle.
- This occurs at the same time a new contraction is taking place in your heart's **RIGHT** ventricle.



How Blood Flows

- So, we've got *four chambers that work together to push blood into a specific fashion.*
- The heart contract as two separate units, a **top unit** and a **bottom unit**.
- The two top chambers of the heart work as a unit. When the right atrium contracts, it forces blood into the right ventricle. When the left atrium contracts, it forces blood into the left ventricle. Blood is flowing from the top of the heart into the bottom of the heart at the same time on both side of the heart.
- A split second later, the two bottom chambers contract at the same time sending blood up and into the lungs and body
- For the heart to work well, your blood must flow in only one direction. Your heart's valves make this possible. Both of your heart's ventricles have an "in" (inlet) valve from the atria into the heart and an "out" (outlet) valve leading to your arteries that goes away from the heart.
- Valves open and close in exact coordination with the pumping action of your heart's atria and ventricles. Each valve has a set of flaps called leaflets or cusps that seal or open the valve. This allows blood to pass through the chambers and into your arteries without backing up or flowing backward.



APPENDIX C: PARTICIPANT PROFILE

1. College Major_____
2. Age_____
3. Sex ___Female ___Male ___Other
4. Race ___Black/African American
 ___White/Caucasian
 ___Hispanic
 ___Asian
 ___Other: (Please specify) _____
5. Age of hearing loss _____ Birth
 _____ 0-3
 _____ Other (Specify) _____
6. Deaf family _____ None
 _____ Parent(s)
 _____ Sibling(s)
 _____ Other: (Specify) _____
 _____ Unknown

APPENDIX D: COMPREHENSION TEST

Directions: Select the answer that best answers the question.

1. Which valve functions most like the tricuspid?
 - A. Pulmonary
 - B. Aortic
 - C. Mitral (Bicuspid)
 - D. Superior Vena Cava

2. When the blood is being forced out of the aorta, at the same time, it is also being forced out of the _____.
 - A. Pulmonary Veins
 - B. Pulmonary Arteries
 - C. Superior Vena Cava
 - D. Cardiac Artery

3. The contraction impulse in the heart starts in _____.
 - A. The Right Atrium
 - B. Both ventricles simultaneously
 - C. Both Atria simultaneously
 - D. The Arteries

4. During the first contraction, in what position will the mitral valve be _____?
 - A. Beginning to open
 - B. Open
 - C. Beginning to close
 - D. Closed

5. During the second contraction, blood is being forced away from the heart through the _____.
 - A. Pulmonary and Aortic Arteries
 - B. Superior and Inferior Vena Cavae
 - C. Tricuspid and Mitral Valves
 - D. Pulmonary Veins

6. When the heart contracts, the _____.

- A. Atria & Ventricles contract simultaneously
 - B. Ventricles contract first, then the atria
 - C. Right side contracts first, then the left side
 - D. Atria contract first, then the ventricles
7. When the blood leaves the heart through the pulmonary artery, at the same time, it leaves the heart through the _____.
- A. Tricuspid Valve
 - B. Pulmonary veins
 - C. Aorta
 - D. Pulmonary Valve
8. When the ventricles contract, blood is forced out of the _____.
- A. Superior and Inferior Vena Cava
 - B. Pulmonary veins
 - C. Tricuspid and Mitral Valves
 - D. Pulmonary and Aortic Valves
9. Blood leaving the heart through the aorta had left the heart previously through the _____.
- A. Vena cava
 - B. Pulmonary veins
 - C. Pulmonary artery
 - D. Tricuspid and Mitral Valves
10. Blood is being forced out the atria simultaneously as blood is _____.
- A. Entering only the vena cava
 - B. Being forced out the pulmonary and aortic valves
 - C. Passing through the tricuspid & mitral valves
 - D. Being forced out through the pulmonary artery

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2016 - Present

KSD Director of Instruction, Kentucky Department of Education, 2012-2016

State School Deputy Director, Kentucky Department of Education, 2008-2012

KSD Information Technology Teacher, Kentucky Department of Education, 2006-2008

Cooperative Education Teacher, Greenwood Public Schools, 2003-2006

Honors

Bill Gates Graduate Fellowship, 2005-2010

Commonwealth Incentive Award Recipient, 2007

Bill Gates Millennium Scholar, 1999-2004

Presentations

Matthews, S. & Begley, W. (2015). *CCR Exchange Program...Where Multiple Languages, Cultures and Career Pathways Come Together*. Presented at Kentucky Council for Exceptional Children, Louisville, KY.

Research Interest

Instructional Design and Online Learning

Cognitive Load Theory

Assessment and evaluation techniques for struggling learners

Learning with multimedia

Service

Director at Large, Kentucky Association of School Boards, 2014 – Present

Leadership Planning Committee, Kentucky Association of School Administrators (KASA), 2015 - Present

Appointed Member, State Rehabilitation Council, 2010-2012